SPECIAL ASTRONOMY SECTION: Eclipses, Stargazing and More! p.57

Discover

SCIENCE FOR THE CURIOUS

November 2015

NEW SPECIES!

Mysteries of the DEEP

Exclusive photos never before seen p.38

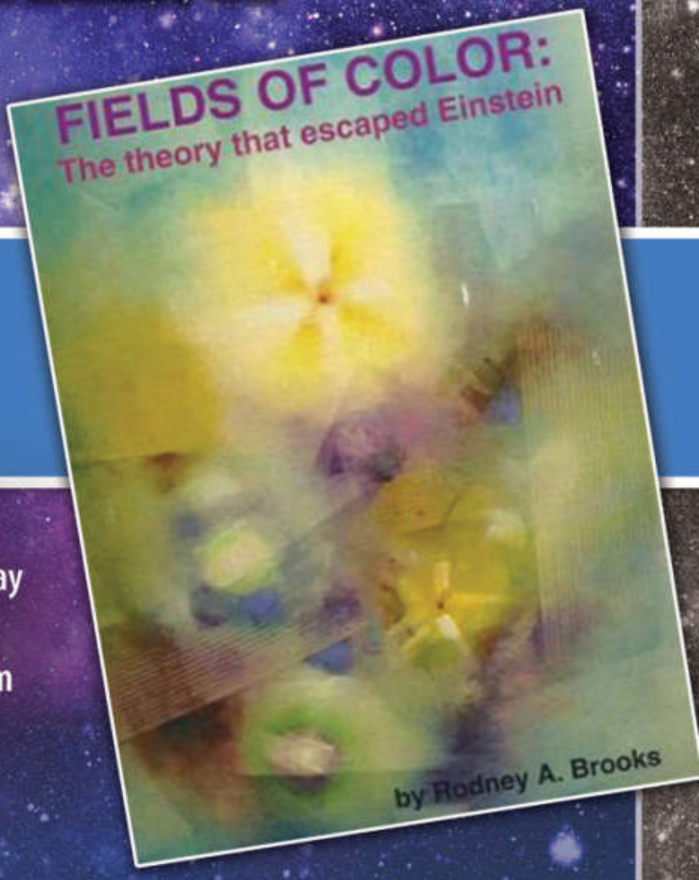
A new type of jellyfish (center) from the genus *Eutiara*.

PLUS

BONUS ONLINE CONTENT CODE p.5

"If you can't explain it simply, you don't understand it well enough"

-Albert Einstein, 1951



For all who want to **UNDERSTAND PHYSICS,** the answer is here!

"Fields of Color" explains quantum field theory to a lay audience without equations. It shows how this often overlooked theory resolves the weirdness of quantum mechanics and the paradoxes of relativity.

amazon reviews

See What Amazon Readers are Saying:

★★★★★ **This is an excellent introduction to quantum physics presented in laypersons language.** *It takes a highly complex and counterintuitive set of concepts and provides a logical analysis.*

★★★★★ **Clear and enjoyable explanation of Quantum Field Theory.** *This is the best presentation that I've found so far of the field theory of quantum physics.*

★★★★★ **Physics for everyone.** *I love the book because physics is presented here as a nice and entertaining story. Which - in fact - it is.*

★★★★★ **Things are explained that we took for granted.** *A deeply thought-out explanation for many 'things' in our world: gravity, colors we see, etc.*

★★★★★ **Gives a good concise history of major discoveries in physics** *...takes an interesting approach to explain the forces of nature using a color code, and Quantum Field Theory.*

★★★★★ **Must be read for those who like a "logic" challenge.** *Good, convincing and clear explanations ....A must read if you like to know more about the reality of the universe.*

To buy or look inside visit: **www.quantum-fields-theory.net**

DISCOVER NEW WORLDS

EXPLORE
them all with *Discover* magazine!

GET 10 issues for just $19.95.
SAVE 67%* off the cover price!

SUBSCRIBE ONLINE AT:
DiscoverMagazine.com or call 800-829-9132

*Savings is based on annual U.S. newsstand price.

P26414

Contents

NOVEMBER 2015
VOL. 36, NO. 9

A view of a northeastern section of Tel Megiddo's remains.

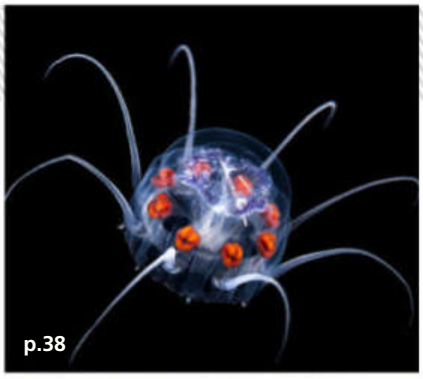
ON THE COVER *Photos by Anthony Berberian and Fabien Michenet*

Website access code: DSD1511
Enter this code at: **www.DiscoverMagazine.com/code**
to gain access to exclusive subscriber content.

FEATURES

COVER STORY

COLUMNS & DEPARTMENTS


p.38


p.22


p.57

OPPOSITE: MEGIDDO EXPEDITION/TEL AVIV UNIVERSITY; THIS PAGE FROM TOP: ANTHONY BERBERIAN AND FABIEN MICHENET; MERIEL JANE WAISSMAN/ISTOCK; BEN COOPER/LAUNCHPHOTOGRAPHY.COM

Editor's Note

A Foreshadowing

A tale of two eclipses — and possibly the adventure of a lifetime.

A few months ago, a friend of mine excitedly informed me that he had secured a campground site somewhere, I believe, near Casper, Wyo.

"For the eclipse," he added when he saw the blank look on my face. "We'll be right in the shadow. Right in the *path* of it. You can come if you want, but you'll need to bring your own sleeping bag."

"Thanks," I said. "But … that's two years from now."

"I know," my friend said, nodding gratefully. "I was lucky to get the spot this late in the game!"

The total solar eclipse in August of 2017 — the first such eclipse crossing the continental U.S. in nearly 40 years — is going to be the very definition of "a big deal," and excitement is already building for it. Writer Michael Bakich, a senior editor at *Discover's* sister publication, *Astronomy*, will tell you all about it on page 66 of our expanded Out There department. Watch for the occasional supersize version of Out There in this and future issues!

Of course, if you don't feel like waiting until 2017 to experience totality and you're in the mood for the adventure of a lifetime, our partners at TravelQuest still have a few spots open on their trip to see a total solar eclipse in Bali next March. (Visit DiscoverMagazine.com/trips-tours for more details.) That's just a few short months away — and no, you won't need to bring your own sleeping bag.

NEXT ISSUE: *Look to the heavens with "stellar archaeologists" seeking the origins of the first stars. Also: Facial recognition technology is growing by leaps and bounds. Find out how it's changing the, er, face of everything from social media to law enforcement. See you next time!*

Stephen C. George, **EDITOR IN CHIEF**

ON THE WEB

November marks the 100th anniversary of Einstein's publication of the gravitational field equations of general relativity. To celebrate, check out our Einstein coverage and stories at **DiscoverMagazine.com/Einstein**

CONNECT WITH US

facebook.com/DiscoverMag
twitter.com/DiscoverMag
plus.google.com/+discovermagazine

SCIENCE FOR THE CURIOUS
Discover

STEPHEN C. GEORGE Editor In Chief
DAN BISHOP Design Director

EDITORIAL
KATHI KUBE Managing Editor
BECKY LANG Senior Editor
GEMMA TARLACH Senior Associate Editor
BILL ANDREWS Associate Editor
APRIL REESE Associate Editor
LACY SCHLEY Assistant Editor
COREY S. POWELL Editor At Large
DAVE LEE Copy Editor
ELISA R. NECKAR Editorial Assistant

Contributing Editors
DAN FERBER, TIM FOLGER, LINDA MARSA, KAT MCGOWAN, STEVE NADIS, JILL NEIMARK, ADAM PIORE, JULIE REHMEYER, ERIK VANCE, PAMELA WEINTRAUB, JEFF WHEELWRIGHT, DARLENE CAVALIER (SPECIAL PROJECTS)

ART
ERNIE MASTROIANNI Photo Editor
ALISON MACKEY Associate Art Director

DISCOVERMAGAZINE.COM
LISA RAFFENSPERGER Web Editor
CARL ENGELKING Staff Writer

Bloggers
MEREDITH CARPENTER, LILLIAN FRITZ-LAYLIN, JEREMY HSU, REBECCA KRESTON, JEFFREY MARLOW, NEUROSKEPTIC, ELIZABETH PRESTON, SCISTARTER, CHRISTIE WILCOX, TOM YULSMAN

ADVERTISING
STEVE MENI Advertising Sales Manager
888 558 1544
smeni@discovermagazine.com

Rummel Media Connections
KRISTI RUMMEL Consulting and Media Sales
608 435 6220
kristi@rummelmedia.com
MELANIE DECARLI Marketing Architect
BOB RATTNER Research
DARYL PAGEL Advertising Services

KALMBACH PUBLISHING CO.
CHARLES R. CROFT President
KEVIN P. KEEFE Vice President, Editorial
DANIEL R. LANCE Senior V.P., Sales & Marketing
JAMES R. MCCANN Vice President, Finance
NICOLE MCGUIRE Vice President, Consumer Marketing
JAMES SCHWEDER Vice President, Technology
DIANE M. BACHA Editorial Director
ANN E. SMITH Corporate Advertising Director
MAUREEN M. SCHIMMEL Corporate Art Director
KIM REDMOND Single Copy Specialist
MIKE SOLIDAY Art and Production Manager

SUBSCRIPTIONS
In the U.S., $29.95 for one year; in Canada, $39.95 for one year (U.S. funds only), includes GST, BN 12271 3209RT; other foreign countries, $44.95 for one year (U.S. funds only).

SUBSCRIBER INQUIRIES
800 829 9132
DCRcustserv@cdsfulfillment.com
P.O. Box 37807, Boone, IA 50037
Back issues available.

EDITORIAL INQUIRIES
editorial@DiscoverMagazine.com
21027 Crossroads Circle, Waukesha, WI 53186

Alliance for Audited Media
KALMBACH PUBLISHING CO.

WILLIAM ZUBACK/DISCOVER

THE CRUX

The Latest Science News & Notes

WATER FAIRIES

These egg-beater-shaped structures are actually water-repellent hairs found on the leaves of *Salvinia natans*, or water ferns. About a millimeter tall, the hairs — known as superhydrophobic trichomes — trap a thin layer of air between the fern leaves and the surrounding liquid to improve stability in water. The Salvinia effect has drawn the attention of researchers developing coatings that could reduce the drag created by ships' hulls traveling through water. — ERNIE MASTROIANNI; PHOTO BY POWER AND SYRED/SCIENCE PHOTO LIBRARY

MEET THE LEAN, GREEN FLYING MACHINE

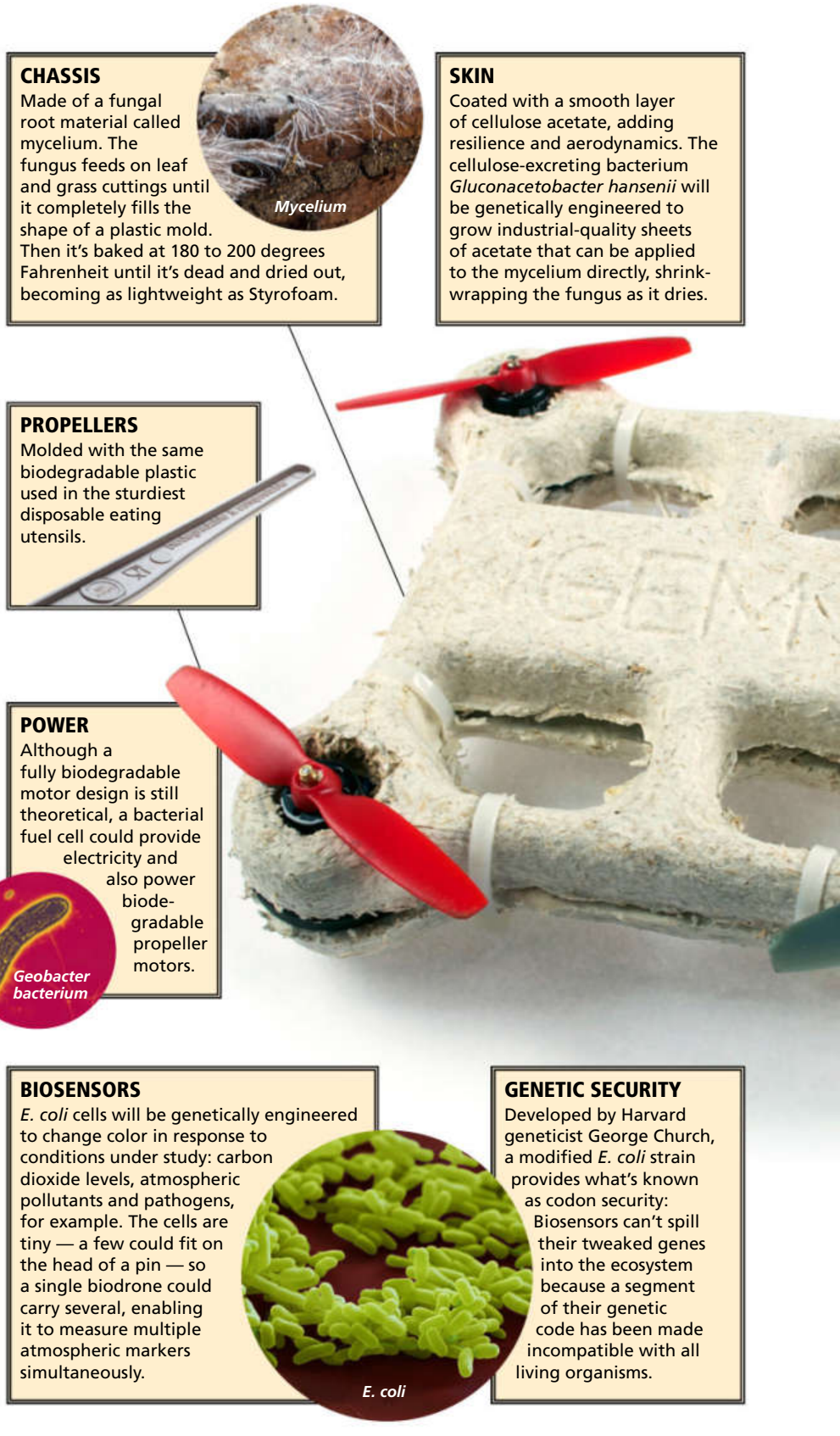
A new kind of drone is inspired by nature — and designed to protect it.

In 2013, a 400-pound research drone went missing off the coast of Alaska, threatening the very environment that the scientists were studying. Fortunately, the fuel tank didn't rupture, and fishermen recovered the wreckage without mishap.

But the near-miss inspired NASA biologist Lynn Rothschild to design a new kind of drone: one that would have minimal environmental impact if it crashed because it would be made of biodegradable materials, such as bacteria and fungus.

Although Rothschild says it "looks sort of like a dried whole wheat sandwich," the prototype her team developed is flightworthy. And future iterations of her biodrone — such as the one illustrated at right — might even be designed to fly one-way missions that end in an intentional crash, providing a snack for Alaskan salmon when the crafts' work is done.

—JONATHON KEATS



WATERPROOFING

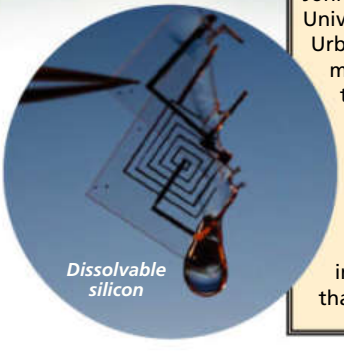
Cellulose acetate loses strength as it absorbs water, so the skin is waterproofed by adding a protein found in paper wasp saliva that makes their nests hydrophobic. The protein coating could be manufactured in yeast cells modified to express the wasp saliva gene.

ACTIVE BIODEGRADATION

A payload of enzymes, like those produced by gut bacteria to aid digestion, will speed the copter's demise when it crashes. Released upon impact, the enzymes will convert remaining bacterial and fungal materials into simple sugars that are harmless to the environment.

DATA TRANSMISSION

Dissolvable cameras could monitor the biosensor readouts. The cameras, pioneered by engineer John Rogers while at the University of Illinois at Urbana-Champaign, are made of ultrathin silicon that rapidly degrades in liquid. Electronics to transmit data to the researchers — and to control the drone — could be printed on a sheet of cellulose acetate in silver nanoparticle ink that dissolves in water.



COUNTERCLOCKWISE FROM TOP LEFT: CHANUS/SHUTTERSTOCK; LUCAFABBIAN/ISTOCK; DEREK LOVLEY/SCIENCE SOURCE; EYE OF SCIENCE/SCIENCE SOURCE; UNIVERSITY OF ILLINOIS/BECKMAN INSTITUTE; NOLUMA/ISTOCK; DAVID SCHARF/SCIENCE SOURCE. CENTER: NASA/AMES

A Lab in Your Pocket

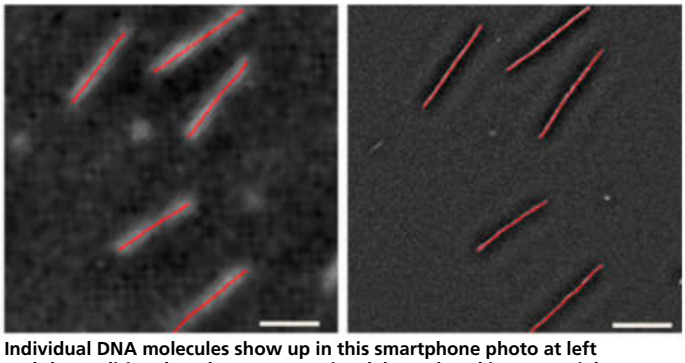
Cheap and lightweight equipment turns smartphones into portable DNA analyzers.

Our DNA defines us, but it can also betray us. Sections of our genetic code that get deleted or duplicated when DNA is copied — errors known as copy-number variations — may increase our susceptibility to afflictions like Alzheimer's disease and malaria.

Unfortunately, the equipment required to diagnose copy-number variations is typically bulky and expensive. Now, researchers at the University of California, Los Angeles, have shown how to turn a regular smartphone into a portable, inexpensive microscope that accurately measures copy-number variations in seconds.

Engineer Aydogan Ozcan and his team created their mobile microscopy unit by souping up the camera of a Nokia Lumia 1020 smartphone. They attached an external lens, filters, focuser and laser, adding less than 7 ounces. After placing a DNA sample on a glass coverslip, the researchers use the laser to excite the DNA molecules and make them visible. The smartphone's camera then snaps a picture of the coverslip through its lenses and filters. Finally, the image is sent to a UCLA server for digital processing.

Ozcan and his colleagues demonstrated that their $400 setup could identify copy-number variations and, subsequently, disease risk, replacing detection methods that require hundreds of thousands of dollars of equipment. Medical staff practicing in rural or resource-limited environments would benefit the most from this immediate and low-cost risk assessment, Ozcan suggests. —KATHERINE KORNEI



Individual DNA molecules show up in this smartphone photo at left and the traditional, and more expensive, lab-produced image at right. The researchers superimposed red lines to denote DNA length.

OZCAN RESEARCH LAB AT UCLA

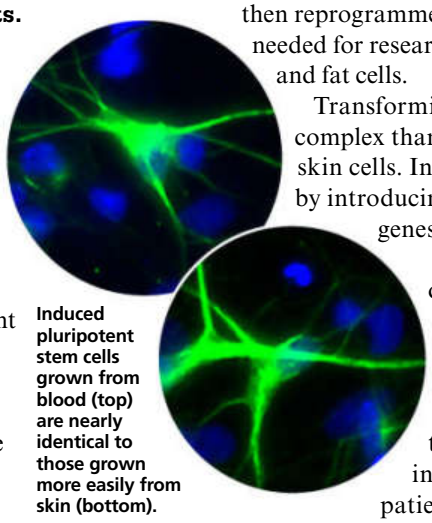
Rewind, Replay, Research Disease

Old blood samples turn into new stem cells that replicate patient pathology.

They had blood, but they wanted guts.

Researchers at Cedars-Sinai Medical Center in Los Angeles had access to thousands of blood samples and detailed clinical records collected from patients over decades. But the diseases that they wanted to study — including inflammatory bowel disease and spinal muscular atrophy — generally did not affect blood cells.

Faced with this quandary, the team spent nearly three years devising a technique to reliably transform what they did have — blood — into induced pluripotent stem cells, or iPSCs. These stem cells, which are similar to highly sought-after embryonic stem cells but derived from adult cells and then reprogrammed, could be turned into the cell types needed for research, including neurons and intestinal and fat cells.



Induced pluripotent stem cells grown from blood (top) are nearly identical to those grown more easily from skin (bottom).

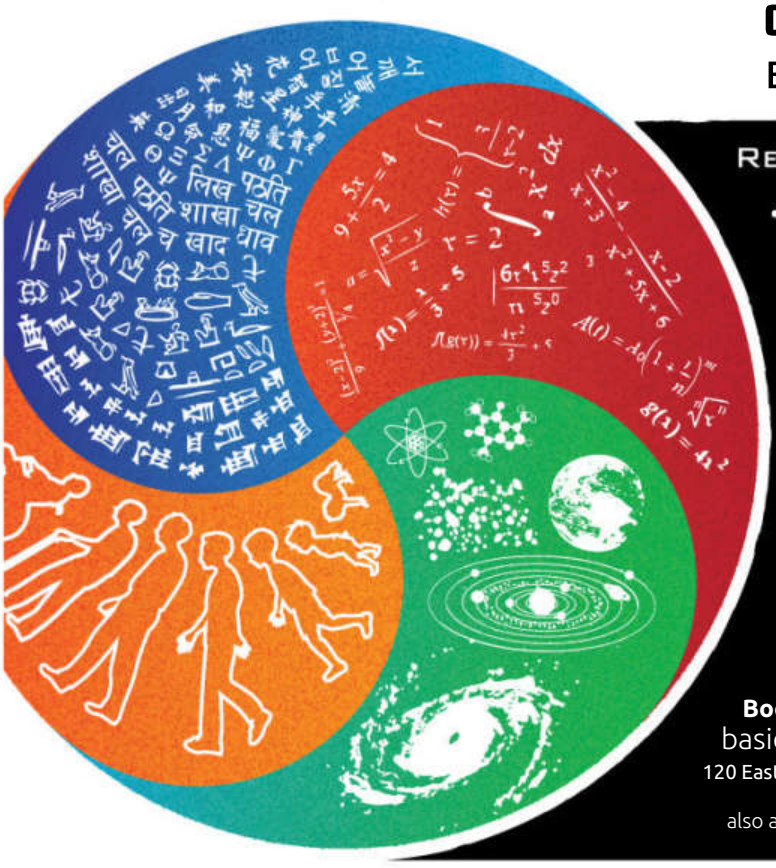
Transforming blood cells into iPSCs is more complex than other methods, such as using a patient's skin cells. In the new technique, cells are redirected by introducing a complex cocktail of seven different genes, known as reprogramming factors.

Researchers have already developed dozens of patient-specific cell lines using this new method. Dhruv Sareen, director of the Cedars-Sinai iPSC Core Facility, says the procedure allows researchers to essentially replicate the conditions and trajectory of an individual's illness: "It's like replaying the patient's disease in the dish." —CALEB O'BRIEN

STEM CELLS TRANSLATIONAL MEDICINE/ALPHA MED PRESS/DOI: 10.5966/SCTM.2014-0121/REPRINTED WITH PERMISSION

THE MECHANICAL THEORY OF EVERYTHING

BY JOSEPH M. BROWN



READ THIS BOOK TO FIND

- WHERE ENERGY COMES FROM
- HOW A PHOTON DISSIPATES IN TEN BILLION YEARS
- WHAT ELECTRONS AND PROTONS ARE MADE OF
- THE SOLUTION TO EINSTEIN'S UNIFIED FIELD THEORY
- HOW LANGUAGE IS MADE
- AND WHY WE AGE

CONTRIBUTORS

DR. JOSEPH M. BROWN
DR. DARELL B. HARMON JR.
DR. LEON A. STEINERT
DR. ROBERT M. WOOD

$40

Book Available Now at
basicresearchpress.com
120 East Main St. Starkville, MS 39759
662-323-2844
also available at Amazon.com

BRP Basic Research Press

ISBN: 978-0-9712944-9-3

Hot, Dry and Dinosaur-Free

Why larger dinos stayed out of the tropics for 30 million years.

May 2015 issue

Did the age of dinosaurs begin with a roar or a whimper? Some scientists suspect the latter. The first dinosaurs appeared around 230 million years ago, but for the next 30 million years, all but the very smallest were restricted to the world's high latitudes, far from the equator — even though the continents were connected, with no barriers to prevent large dinosaurs from moving around.

Discover featured this mystery recently ("Sands of Time," May 2015), as well as a theory that might explain it. Some researchers believe that big dinosaurs were held back by the unstable tropical climate of a "hothouse" world, when carbon dioxide levels skyrocketed to six times their present value.

A new study provides compelling evidence that this is true. Researchers analyzed fossilized pollen and carbon isotopes in New Mexico rock layers to reconstruct the equatorial climate between 205 million and 215 million years ago. They found that it swung wildly between wet and dry spells.

"It comes down to resource requirements," says Randall Irmis, a paleontologist with the Natural History Museum of Utah in Salt Lake City, who was part of the team. Large, fast-growing dinosaurs "could not contend with this really changing environment that made resources scarce and unpredictable." — DOUGLAS FOX

COLLECTOR'S SET

8 *for* $8

at Face Value!

Get a Complete 8-Coin Set of 2015 Presidential Dollars at *face value of $8!* You'll receive Uncirculated Philadelphia "P" and Denver "D" issues of all four 2015 designs – honoring Presidents Harry S. Truman, Dwight D. Eisenhower, John F. Kennedy and Lyndon B. Johnson! These 2015 coins are struck for 3 months each and will never be minted again. Get the 8-coin year set at **FACE VALUE – *limit one set!***

SAVE 65% *plus* receive a FREE GIFT

Order your Complete Uncirculated 8-coin set today at face value of ***ONLY $8*** and **SAVE 65%** off the regular price of ~~$22.95~~. Plus, respond by deadline and get a **FREE** Uncirculated 2015 Bombay Hook National Park quarter, honoring a national wildlife refuge in Delaware. With tidal salt marshes, freshwater pools and timbered swamps, this is a natural sanctuary for migrating waterfowl.

You'll also receive our fully illustrated catalog, plus other fascinating selections from our Free Examination Coins-on-Approval Service, from which you may purchase any or none of the coins – return balance in 15 days – with option to cancel at any time. ***Order your complete 8-coin set and SAVE!***

Mail coupon today or order online at:
www.LittletonCoin.com/specials

45-Day Money Back Guarantee of Satisfaction

*Get a **FREE** Uncirculated 2015 Bombay Hook Quarter when you order by deadline.*

Special Offer for New Customers Only

☑**YES!** Please send me a Complete Uncirculated 8-Coin Set of 2015 P&D Presidential Dollars at FACE VALUE OF ONLY $8.00 – regularly ~~$22.95~~, plus Free Shipping (limit 1 set). Also send my **FREE** Uncirculated 2015 Bombay Hook Quarter (one per customer, please).

SAVE! *Add Custom 2007-Date Presidential Dollar Display Folders for $2.95 – regularly ~~$3.49~~ – and **SAVE!***

Name _____
Please print your complete name and address clearly

Address _____ Apt# _____

City _____ State ____ Zip _____

E-Mail _____

QTY	DESCRIPTION	PRICE	TOTAL
1	8-Coin Collector's Set *(limit 1 set)*	$8.00	$8.00
	*Display Folders – **SAVE 15%***	$2.95	
	***FREE** Shipping!* Merchandise **TOTAL**		$

Order Deadline: 12:00 Midnight, December 31, 2015

❑ Check or Money Order payable to Littleton Coin Company

Charge my: ❑ VISA ❑ MasterCard ❑ American Express ❑ Discover Network

Card No. _____ Exp. Date ____/____

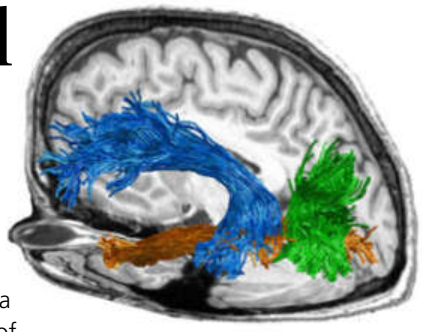
Please send coupon to:

Littleton Coin Co®, Dept. 3XZ408
1309 Mt. Eustis Rd, Littleton NH 03561-3737

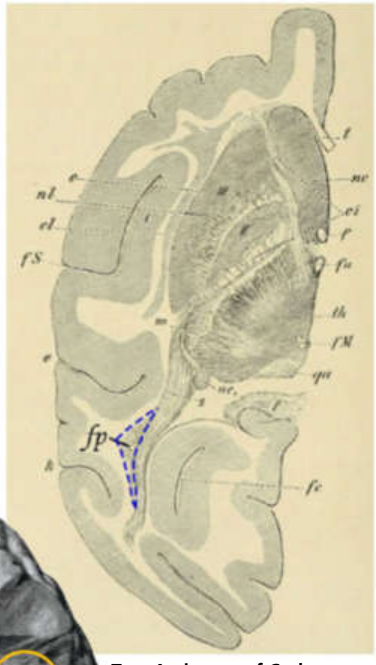
America's Favorite Coin Source • TRUSTED SINCE 1945

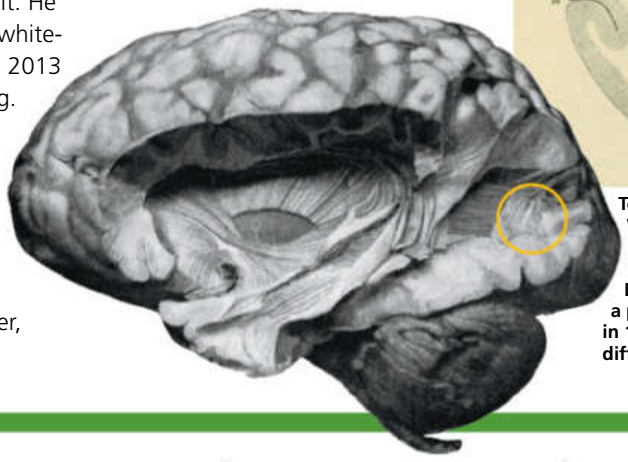
Lost and Found

How a pair of scientists rediscovered a part of the human brain.



Modern imaging shows the brain structure that Jason Yeatman and Kevin Weiner rediscovered, the VOF, highlighted in green. Knowledge of this piece of anatomy had fallen out of medical texts until recently.





Top: An image of Carl Wernicke's original 1881 identification of the VOF in the brain of a monkey. Left: The VOF identified in a postmortem human brain in 1909, but labeled with a different name.

While examining colorful 3-D brain images, Stanford psychology graduate student Jason Yeatman spotted a part of the brain he'd never learned about in class. But what he thought was a discovery was actually a rediscovery — a snippet of brain anatomy lost to science for decades.

The vertical occipital fasciculus (VOF) debuted in an atlas by German psychiatrist and anatomist Carl Wernicke in 1881. It had all but vanished from scientific literature when Yeatman noticed it. He published his find of the VOF, a bundle of white-matter fibers near the back of the brain, in 2013 and helped show its involvement in reading.

Yeatman, now an assistant professor at the University of Washington, then enlisted fellow postdoc researcher Kevin Weiner to learn why the VOF fell out of sight. Their findings appeared in *Proceedings of the National Academy of Sciences*. Weiner, now a Stanford researcher, recalls how they figured it out.

IN HIS OWN WORDS

I got bitten by the history-of-neuroscience bug a long time ago — I like looking at old papers. They're written in a more colloquial manner. When Jason came to me, I immediately agreed, and it turned into a fun little journey. Every single name and date, every single atlas, led us to another name and date or another atlas or another paper. I would look at pictures and hack my way through the German.

Kevin Weiner studies an 1897 brain atlas by Carl Wernicke.

We saw decades' worth of publications where scientists argued that the VOF didn't exist. The most aggressive argument came in 1891, and it was based on the fact that it didn't exist in a calf embryo! How is that logical? But it didn't matter: Atlases afterward repeated this argument against Wernicke's finding, which perpetuated doubt in the VOF's existence.

Then we found a 1909 journal article with beautiful images of the VOF from dissections of dead human brains. It was so consistent with our images of living human brains. The author laid out a how-to list to find the VOF, and it became clear why others missed it: It is about half an inch from the surface of the brain. If you were rough with the brain during dissection, you could actually rip the VOF right off and never see it.

To make matters worse, there was a movement in the late 1890s and early 1900s to reduce the amount of anatomical names from 35,000 to 4,500. So thousands of anatomical structures were just written out of these atlases — and of history.

I can't give you a number as to how many structures have been forgotten or overlooked, but this isn't the only one. Our whole paper is about trying to evolve from what could be called poetic descriptions of anatomy to more computational approaches so that we can prevent this sort of thing. We built an algorithm to automatically identify the VOF from brain scans, and it works. People who downloaded it can see the VOF in every single brain! It's really nice when that happens.

— AS TOLD TO JENNY BLAIR

CLOCKWISE FROM TOP: JASON YEATMAN; WERNICKE 1881; CURRAN 1909; JASON YEATMAN

Ask Discover

Q Where do different flu strain names, like H1N1 and H7N9, come from?
— Claudia Mulder, Perth Amboy, NJ

A First, let's take a step back. Influenza viruses are divided into three categories: A, B and C, depending on their antigen protein type. (Antigens are any foreign substance that can stimulate an immune response, typically spurring antibody production.) Whereas type C can cause mild respiratory illness and B seasonal epidemics, type A can lead to serious worldwide pandemics and is the type you're most likely to hear about in the news.

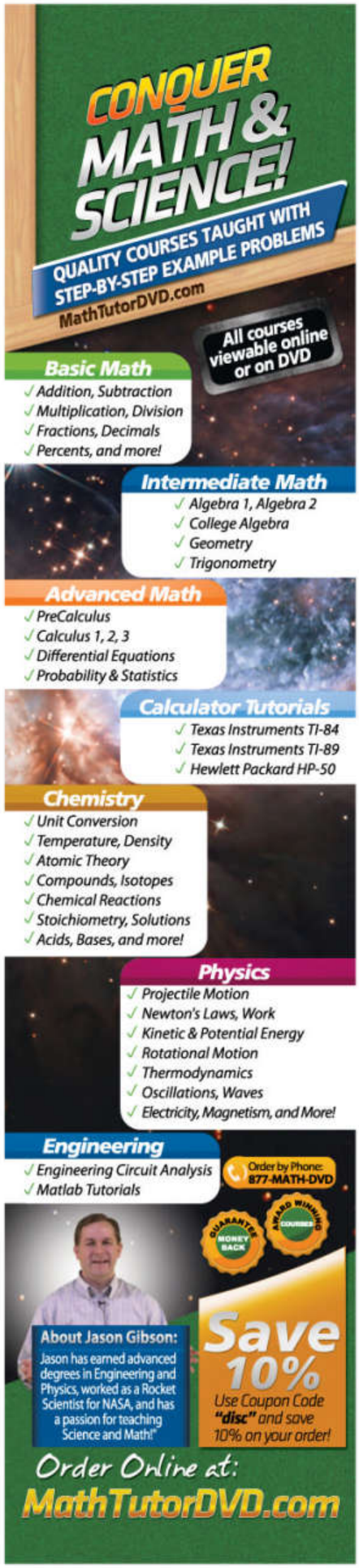
The World Health Organization, which adopted the classification system in 1979, further divided influenza A based on its surface glycoproteins, hemagglutinin (H) and neuraminidase (N). Hemagglutinin, which plays a role in how the virus binds to host cells, has 18 known types; neuraminidase, which helps the virus detach from the cell so it can spread through the body, has 11. The resulting 198 possible subtypes, from H1N1 to H18N11, could all be called "bird flu" because wild birds are influenza A's natural reservoirs. A handful, however, can infect humans. —BRENDA POPPY

Visit **DiscoverMagazine.com/Ask** for more answers. To submit a question, send an email to **Ask@DiscoverMagazine.com**

SCIENCE PICTURE CO./SCIENCE SOURCE

DID YOU KNOW?

Apparently, kangaroos are left-handed. Although scientists have long believed that favoring one hand over another is a uniquely primate characteristic, a recent study in *Current Biology* suggests otherwise: Observation of red and eastern gray kangaroos showed a strong preference for left forelimb use, strengthening beliefs that handedness is connected to bipedal posture.

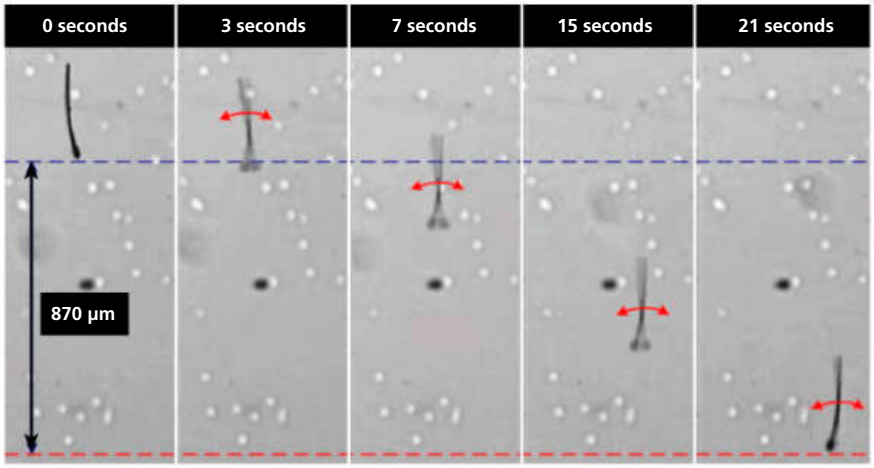


Swim, Sperm Robots, Swim

To transport goods within the body, scientists turn to a familiar design.

If you could shrink yourself down to the size of a bacterium and explore a watery pool, your normal swimming technique would soon prove worthless. Liquids feel thicker, more like moving through honey than water, and tiny swimmers are easily jostled off course. So when an international team of engineers wanted to design tiny robots that could move cells around, deliver drugs deep inside the body or clean clogged arteries, they looked to nature for inspiration: sperm.

The team's "magnetosperm" are small, about the size of a dust mite, but six times longer than a human sperm cell. Their design mimics the familiar swimmer's physique, with a thin magnetic disk added to the head. To get the sperm to swim in liquid, the researchers switch on an oscillating magnetic field — an effect roughly equivalent to making jazz hands while holding a bar magnet. The changing field direction makes the sperm's body wiggle, propelling the sperm-bot forward. The magnetosperm need only weak magnetic fields to swim, so the robots should still work well in deep tissue, farther from the source of the oscillations.



Magnetosperm — six times longer but roughly the same shape as their natural brethren — might be the drug delivery bots of tomorrow. Weak magnetic fields cause the device to waggle its body, pushing it forward by 870 micrometers (just under a millimeter) in 21 seconds.

The next steps are to make the magnetosperm even smaller and to test them in environments that more closely mimic the human body, the researchers say. — JENNY MORBER

INBOX

Back to School?

Several readers were quick to point out an error in "Super Earths," from our September issue.

Adam Hadhazy's article states: "From your old [high school physics] notes: Density equals volume divided by mass." Hmm. Not in my old notes. How about mass divided by volume?

Nicholas O'Dell *Kimberton, PA*

Nicholas, you're right, of course. Apparently our old physics notes weren't that good. Actually, our history notes could use a brush-up, too: In "Germany's Bright Idea," from the July/August 2015 issue, we said Reagan defeated Carter in 1979. Once again, a reader caught our error:

The Carter-Reagan election was in November 1980, not 1979, and Reagan did not take office until January 1981.

Richard Dornfeld *Aurora, IL*

The Origin Story column in the September issue, "Gut Reaction," references a southern Venezuelan tribe with the highest human microbiome diversity ever seen.

The article mentions "the isolated Yanomami tribe, discovered by Westerners only in 2009." That tribe was studied in depth by high school students at a private high school in La Canada, Calif., in 1986 while I was there as a computer lab assistant.

George Taylor *Los Angeles*

Senior Associate Editor Gemma Tarlach responds: *As the editor of the story, I had the same reaction when I read the writer's first draft; the Yanomami were discussed during one of my college anthropology classes, and I remembered reading a memoir of a researcher who had lived among them in the '70s. However, our writer assured me (and our independent fact-checker later confirmed) that the particular tribe that participated in the research published in* Science Advances *earlier this year, while part of the broader Yanomami culture, was only discovered by Western researchers in 2009.*

I.S.M. KHALIL/GUC & S. MISRA/U.TWENTE

This Is How To Walk the Walk

The must-have men's accessory once carried by kings, presidents, barons and billionaires is back—and can be yours for ONLY $49!

They call walking the "perfect exercise." It gets your heart pumping, clears your head and fills your lungs with fresh air. Not bad, but we found a way to make it even better. Before you take your next 10,000 steps, add a little strut to your stroll. Take the ***Stauer Gentleman's Walking Stick*** anywhere and I promise that you'll feel like a conquering hero. Heads will turn. Doors will open. Its powers will astound you.

What's the secret? Pure class. Our ***Stauer Gentleman's Walking Stick*** is a tip of the top hat to turn-of-the-century tradition. Today, serious collectors gladly pay thousands for rare and hand-crafted sticks from the 19th century. But only Stauer can deliver a modern version of this vintage classic—that looks and feels as good as the original—for **ONLY $49!**

Hand-carved detail for easy grip!

Image not actual size.

Sticks that make a statement. For centuries, no respectable man was seen in public without a walking stick by his side. They were as indispensable as a fine tailored suit or fancy moustache. Well-heeled men "wore" them as symbols of power and prestige, using elaborately decorated staffs to help navigate trails, dispatch opponents or conceal gadgets and contraband. Simply put, they were the must-have accessory for any sharp-dressed man on the move.

The ultimate travel companion. Hold it once and you can feel that it's not some hollow imitation. Our ***Gentleman's Walking Stick*** is crafted from a solid shaft of imported Sheesham (Indian Rosewood) and finished with layers of black lacquer. The rounded, knob-style head has serious weight and the silver-finished brass features an elegant engraved design that adds flair while improving your grip. And a black rubber tip steadies your stance on all sorts of surfaces from dirt and asphalt walkways to marble floors and Persian rugs.

Your satisfaction is 100% guaranteed. Try the Stauer Gentleman's Walking Stick risk-free for two months. If you're not convinced that it adds sophistication to your stride, simply send it back within 60 days for a complete refund of your purchase price. But we're betting that after your first step with this stick, you'll never walk alone again!

Stauer Gentleman's Walking Stick ~~$79*~~

Offer Code Price— **$49** + s&p **Save $30**

You must use the insider offer code to get our special price.

1-800-859-1736

Offer Code SWS260-01
Please use this code when you order to receive your discount.

TAKE 38% OFF INSTANTLY!
When you use your INSIDER OFFER CODE

Stauer®
14101 Southcross Drive W.,
Dept. SWS260-01,
Burnsville, Minnesota 55337
www.stauer.com

BBB ACCREDITED BUSINESS
Rating of A+

** Discount for customers who use the offer code versus the listed original Stauer.com price.*

• 36" long • Solid silver-finished brass handle • Supports up to 250 lbs. • Imported Sheesham wood

Smart Luxuries—Surprising Prices™

Medium-Size Black Hole Is Just Right

Discovery could help explain where the biggest ones come from.

After decades of searching, astronomers have finally found a medium-size black hole. About 12 million light-years distant in galaxy M82, middleweight M82 X-1 is bigger than the black holes left over from stars' deaths, but it's not big enough to be supermassive.

Astronomers had long thought such in-betweeners *might* exist and believed they *might* be catching glimpses of them, but they had no solid proof. University of Maryland's Dheeraj Pasham set out to change that. While no one can see a black hole by definition, an X-ray telescope can see the orbiting material around that black hole, which is so hot it emits high-energy radiation.

Galaxy M82, about 12 million light-years away, is home to the first confirmed middleweight black hole: M82 X-1.

Pasham studied six years' worth of X-ray data from M82 X-1. He found two repeating signals. The time between blasts gives clues about how fast and how far the orbiting gas is from the hole's center — in other words, whether the black hole has small, medium or large gravitational force. Pasham ran the numbers: M82 X-1 is about 400 times as massive as the sun. It is the first time an astronomer confirmed a black hole that is definitely "intermediate mass."

So where did it come from? Nobody knows. "Its formation requires a new astrophysical phenomenon," says Pasham; several theoretical models exist that could explain it, but none has been proven to be accurate. But these medium black holes might just be the seeds that grow into the supermassive ones. Their existence alone, whatever the origin, could explain how their gargantuan cousins got here. To know for sure, astronomers will have to keep finding these cosmic rarities. – SARAH SCOLES

Japanese quail chicks (*Coturnix japonica*)

Beyond Nature and Nurture

The more your parents bond before you're born, the better adjusted you'll be — at least if you're a Japanese quail. Researchers at the University of Rennes in France studied how bonding in this monogamous species might affect their progeny. They looked at 30 male-female pairs, some of which developed close bonds by staying together all the time, while others met just three times a week for sex. Those bonds mattered: Chicks from the tight-knit parents were more social and less fearful. – DIANA KWON

DID YOU KNOW? **In eastern Washington state, "habitat-enhanced" vineyards — which have added native plants as a strategy to increase "good" insects and reduce pests — are attracting four times as many butterflies as conventional vineyards. We'll drink to that.**

TOP: NASA, ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA). BOTTOM: GENDALF1996/ISTOCK

Introducing ***The new and revolutionary*** **Jacuzzi® Hydrotherapy Shower.**

AGING = PAIN

For many, arthritis and spinal disc degeneration are the most common source of pain, along with hips, knees, shoulders and the neck. In designing the Jacuzzi Hydrotherapy Shower, we worked with expert physicians to maximize its pain relieving therapy by utilizing the correct level of water pressure to provide gentle yet effective hydrotherapy.

JACUZZI® SHOWER = RELIEF

Four Jacuzzi® ShowerPro™ Jets focus on the neck, back, hips, knees and may help ease the pain and discomfort of:

- Arthritis
- Circulation Issues
- Aches and pains
- Neuropathy
- Sciatica
- Inflammation

The Jacuzzi® Hydrotherapy Shower provides a lifetime of comfort and relief… safely and affordably.

As we age, the occasional aches and pains of everyday life become less and less occasional. Most of us are bothered by sore muscles, creaky joints and general fatigue as we go through the day- and it's made worse by everything from exertion and stress to arthritis and a number of other ailments. Sure, there are pills and creams that claim to provide comfort, but there is only one 100% natural way to feel better… hydrotherapy. Now, the world leader in hydrotherapy has invented the only shower that features Jacuzzi® Jets. It's called the Jacuzzi® Hydrotherapy Shower, and it can truly change your life.

For over 50 years, the Jacuzzi® Design Engineers have worked to bring the powerful benefits of soothing hydrotherapy into millions of homes. Now, they've created a system that can fit in the space of your existing bathtub or shower and give you a lifetime of enjoyment, comfort and pain-relief. They've thought of everything. From the high-gloss acrylic surface, slip-resistant flooring, a hand-held shower wand, a comfortable and adjustable seat, to strategically-placed grab bars and lots of storage, this shower has it all.

Why wait to experience the Jacuzzi® Hydrotherapy Shower? Call now… it's the first step in getting relief from those aches and pains.

Call toll free now to get your FREE special report "Tips on Living to be 100"

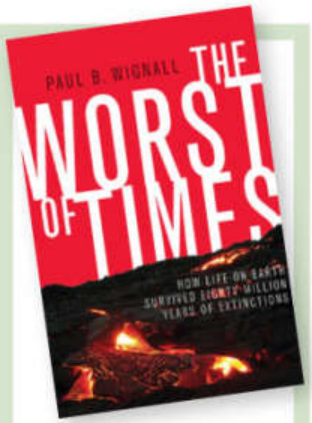
Mention promotional code 101318.

1-888-784-7392

Jacuzzi

© 2015 Aging In The Home Remodelers

82019



THE WORST OF TIMES

How Life on Earth Survived Eighty Million Years of Extinctions

By Paul B. Wignall

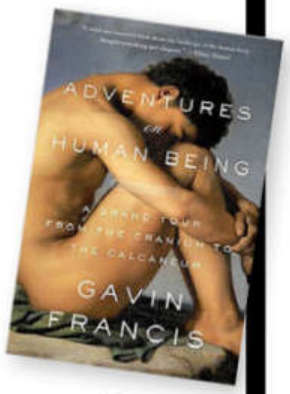
About 250 million years ago, things got very bad indeed. The sheer scale of the Permian-Triassic mass extinction boggles the mind: More than 90 percent of life on Earth was wiped out. And yet, the event set the stage for an explosion of new species. In this scholarly but accessible analysis, geologist Wignall explores the perfect storm of cataclysms, plate tectonics and other forces that led to "The Great Dying" — and the rebound of life in its aftermath.

ADVENTURES IN HUMAN BEING

A Grand Tour From the Cranium to the Calcaneum

By Gavin Francis

Scottish physician Francis racked up awards for his memoir *Empire Antarctica*, which chronicled his time as the doctor at a remote research station at the bottom of the world. He carries over that book's sense of wonder and wit in this intelligent, intimate exploration of human anatomy that draws on history, philosophy and his own experiences in operating rooms and ERs. Francis covers the body from head to toe, literally, opening with a brain surgery assist and closing with ruminations on the humble footprint that's the unique signature of our species.

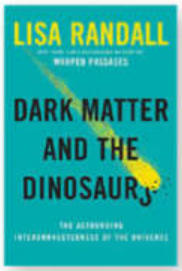


DARK MATTER AND THE DINOSAURS

The Astounding Interconnectedness of the Universe

By Lisa Randall

It's a tall order to cover everything from the Big Bang to today's ongoing Sixth Extinction in a consistently engaging way for a general audience. Particle physicist Randall delivers, peppering serious science with anecdotes about Roombas and fortune cookie messages.



OUR ROBOTS, OURSELVES

Robotics and the Myths of Autonomy

By David A. Mindell

Neither overly optimistic nor doomy, MIT professor Mindell offers a clear-eyed, reasoned overview of current and potential robotics achievements — and why the machines will always need us.

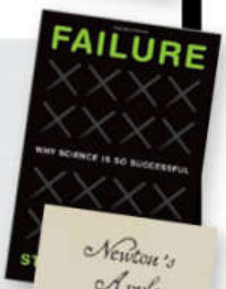
The Truth About Science

FAILURE

Why Science Is So Successful

By Stuart Firestein

The Columbia University professor who gave us the much-discussed *Ignorance* in 2012 returns with the logical sequel: If ignorance is what drives us to imagine solutions, failure is the fuel that takes us further as we zero in on understanding.



NEWTON'S APPLE AND OTHER MYTHS ABOUT SCIENCE

Edited by Ronald L. Numbers and Kostas Kampourakis

"It's probably best to get the bad news out of the way first," writes physicist Daniel P. Thurs. "The so-called scientific method is a myth." His is one of 27 essays in this provocative collection that tackles some of science's most enduring misconceptions and dubious assumptions.

Man's Best Friends

HOW DOGS WORK

By Raymond Coppinger and Mark Feinstein

Almost everything you think you know about dogs is wrong. Forget the loyal companion stereotype, or the idea you've got to show you're the alpha of the pack. Ethologists Coppinger and Feinstein present this most familiar of animals in a new and objective light, analyzing their anatomy and behavior with science rather than sentimentality.

THE HORSE

The Epic History of Our Noble Companion

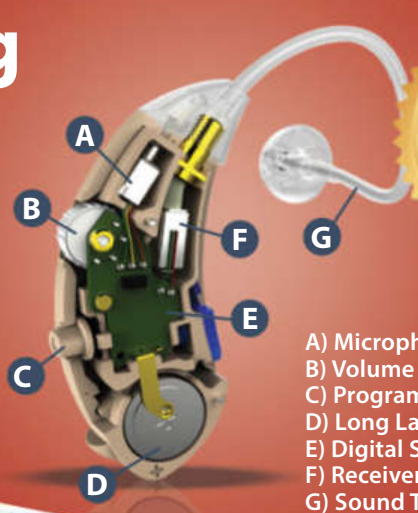
By Wendy Williams

The evolution of horses, and our relationship with them, is arguably the most complex of any domesticated animal. Lifelong equestrian enthusiast Williams takes on the topic at full gallop, weaving scientific analysis with cultural and historical anecdotes in this lively, fascinating read.

—GEMMA TARLACH

Affordable Hearing Aid Technology Only $299!

Learn about our great digital technology at an affordable price.



SAVE $50 ON A PAIR
And Get FREE 1 Year Supply Of Batteries*

A) Microphone
B) Volume Control Wheel
C) Program Button
D) Long Lasting Battery
E) Digital Signal Processor
F) Receiver (Speaker)
G) Sound Tube

The All New HCX!

- ✓ Digital sound processing chip provides **crystal clear sound and makes speech easier to understand** without feedback
- ✓ Multiple memory programs **adapt to most listening situations**
- ✓ Nearly invisible thin tube design
- ✓ Helpful **low battery warning** so you are never caught unprepared
- ✓ **Long lasting size 13 batteries**
- ✓ 10 bands of layered noise reduction helps to **emphasize voices while balancing out background noise**
- ✓ **100% Money Back Guarantee!**

The HCX™

★ Customer Reviews ★

"I will definitely recommend your company to my patients." - *Dr. Arun P.*

"I just want to let you know how happy my husband and myself are with his new hearing aids!..." - *Monique S.*

Studies Show: Hearing Aids MAY HELP PREVENT DEMENTIA

A study by Dr. Frank Lin at the John Hopkins University, found that patients with even a mild hearing loss were two times more likely to develop dementia. Fortunately, hearing aids help address hearing loss and may help prevent cognitive health due to hearing loss.

www.AdvancedHearing.com/Dementia

Digital Hearing Aid Technology... For Only $299!

All hearing aids work the same way. The **microphone** picks up the sound and sends an electrical signal to the digital signal processor. The **digital signal processor** is the "brains" of the hearing aid. It takes the sound it receives and adjusts the sound to amplify important speech sounds as well as filtering out unwanted noise. (To ensure the best in quality, our digital processor is designed and manufactured right here in the **United States.**) Once the processor has amplified the sound, it is passed to the **receiver** (also known as the speaker) which emits a corrected and amplified sound through the **sound tube** into your ear.

Most importantly, your new HCX hearing aids work at a **fraction of the cost** of name-brand hearing aids. In addition to the technical components of the hearing aid, you also have a **volume control** that can be modified with a light touch of the finger. Your new hearing aids come with **3 different audio programs** that help you listen in different sound environments. You will love the Open-fit design, that is so light you probably won't even feel that you are wearing your hearing aids – you'll just be hearing clearly!

You can spend thousands for a high-end hearing aid or you can spend **just $299** for a hearing aid that just plain works (**only $274 each when you buy a pair**). We are so sure you will love our product, that we offer a **100% Money Back Guarantee - Risk Free** if you are not satisfied for any reason. It's time to get great digital technology at an affordable price!

BUY A PAIR AND SAVE $50!

1-877-767-4480

Free 1 Year Supply Of Batteries!

*Use Coupon Code When You Order: **D5A**

Advanced Affordable Hearing
Affordable Quality Since 1996!

BBB ACCREDITED BUSINESS A+

100% MONEY BACK GUARANTEE

RISK FREE Trial

US Company Owned And Operated

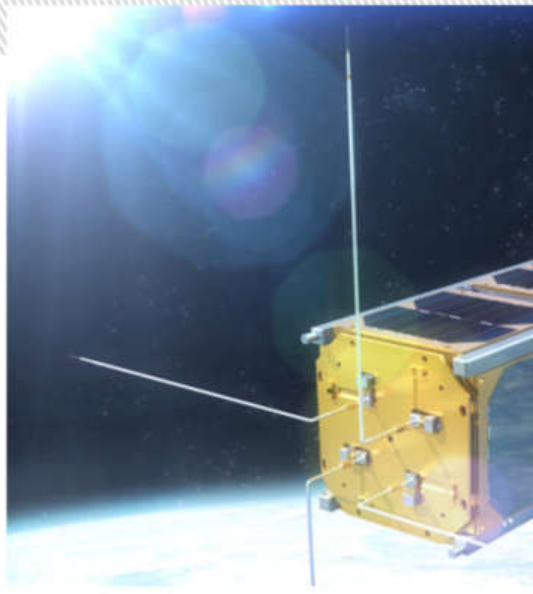
FDA REGISTERED

www.AdvancedHearing.com/D5A

Classroom in the Sky

As technology shrinks, so do satellites, making them accessible to students whose research in space can impact scientific advancements.

BY **CAROLINE BARLOTT**



CHARLES NOKES/ALBERTASAT

Collin Cupido picks up the satellite model and mimics how it will hang in space, moving it around his body as though it were orbiting Earth. The satellite is a CubeSat, a miniature cube-shaped spacecraft or nanosatellite that can conduct experiments in space. Cupido actually holds three linked cubes, altogether about the size of a loaf of bread. Inside that tiny exterior lies one of the best hopes for the future of space research.

The satellite, named Ex-Alta 1, is the first of its kind built at the University of Alberta, says Cupido, a recent graduate and the project's systems leader. But this satellite is just one of 50 being crafted by universities around the world, participating in the QB50 ("cube 50") mission, a project managed by the von Karman Institute for Fluid Dynamics in Belgium as a way to provide hands-on education while conducting scientific experiments in space. QB50 is one of many projects across the globe aimed at getting students — university, high school and even younger — involved in making and operating CubeSats.

Advancing technology has made the tiny spacecraft far more economical than many ever thought possible. CubeSat parts are relatively inexpensive, and the compact end products can hitch rides on rockets that already go to space, a boon to researchers and students alike. Whereas only large national and international space agencies have funded big satellites — which can be the size of a city bus and cost between $50 million and $100 million to build and launch — the tiny Ex-Alta 1 costs about $800,000. The University of Alberta team raised much of the money through a combination of crowdfunding campaigns, space agency grants, university support and donations from aerospace companies, all typical ways teams currently fund these satellite projects.

Collin Cupido prepares to test the structural integrity of his project's tiny satellite. Assuming it passes, the student-built instrument will reveal new findings about Earth's atmosphere.

SPACE PLAYGROUND

Since 2011, through NASA's CubeSat Launch Initiative, 40 small spacecraft have already launched from rockets and produced years' worth of data, while teaching students the basics of space technology. The satellites, shoebox-size and smaller, are technologically advanced enough to study space weather, gather resources from other planets and advance our knowledge of space — all while providing hands-on experience that previous generations would have needed years to achieve.

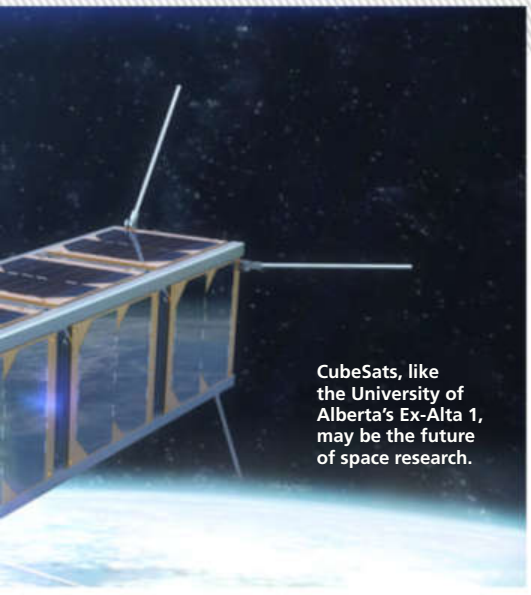
CubeSats started becoming part of the scientific lexicon in the early 2000s, when a Stanford professor wanted to give his students the chance to build and work with space technology.

In 1999, Robert Twiggs, an astronautical engineer now at Morehead State University, helped create the Orbiting Picosatellite Automatic Launcher (OPAL), a microsatellite that can propel several satellites as small as ice cream bars into space. The goal was to see if a mother ship microsatellite could launch smaller daughter ships, with all the satellites capable of sending magnetic field measurements to Earth.

For over two years after its 2000 launch, OPAL worked perfectly. The mission's success inspired Twiggs to create a larger design so that students would have more options for experiments. Costing just $20,000, this blueprint formed the basis from which many cube satellites are now built.

"We initially viewed the CubeSat almost like building a Sputnik," says Twiggs. "Going through all the process and getting it launched and having it work in space, that's quite a process itself — that's what we wanted to use for student education. I didn't conceive of going much beyond the universities."

In 2010 the National Science Foundation teamed up with the University of Michigan to create the first CubeSat with any scientific purpose: studying the effect of space



CubeSats, like the University of Alberta's Ex-Alta 1, may be the future of space research.

ANDY KALE/DEPARTMENT OF PHYSICS/UNIVERSITY OF ALBERTA

weather on radio transmissions or GPS. It worked so well that soon other, richer organizations wanted in on the CubeSat action. The sudden infusion of serious cash into the industry drove up the price of a space launch from $30,000 to $120,000 for an existing single-unit satellite. The once "inexpensive" satellites — created primarily as an educational tool — became too costly for many academic programs.

Costs are still far lower than for any large satellite, but for many schools, it's not a small sum. And to launch their experiments into space on a rocket, they need to be a part of a space agency program. (Cupido says that, if they can, universities that build CubeSats set up some kind of partnership that eventually guarantees them a spot in space.) Not every school has the resources to participate, but this space research is still far more accessible for students now than it's ever been in the past. Nowadays, teachers can order full CubeSat kits — containing all the components necessary to create a satellite — online from leading suppliers in the U.S.

"My generation saw the birth of the Internet. Now, today's students are growing up where satellites are something they can do themselves," says Jason Crusan, director for advanced exploration systems with NASA. "That's pretty revolutionary."

MISSION POSSIBLE

At the University of Alberta lab, Cupido wears a lab coat, a dust mask, a hairnet and gloves as he delicately handles the tiny parts that make up the interior of the Ex-Alta 1. Metal probes extend from the top of the satellite, like antennas, to measure electron density.

The probes, along with an onboard magnetometer, will study and predict space weather once Ex-Alta 1 is in orbit. That's important because space storms can disturb GPS signals and can create problems in communications between airplanes and ground control. A major storm could short out the world's power supply. CubeSats are ideally poised for studying space storms in the lower areas of the atmosphere, which are too high for weather balloons and too low for larger satellites to survive.

"It's an interesting region of the world [and] we should investigate it further," says Jan Thoemel, project manager of the QB50 mission. But it will be months before the satellite will be ready for space with the launch date scheduled for February 2016. QB50 announced the CubeSats will launch from the International Space Station after being transported on rockets already making the journey.

In the meantime, about 50 students gather in a University of Alberta lab twice a week, preparing for the time when they'll actually communicate with the orbiting spacecraft. Simulators allow them to practice determining battery levels, communicating with the satellite and analyzing mechanical vibrations and stresses on the structure.

"The satellite is essentially a robot with a radio, sensors, eyes and ears. You talk to it a couple of times a day; the rest of the time, it needs to know what to do by itself," says Cupido. As a result, he and the students have learned a lot about how to make reliable platforms that can function on their own. Even before the satellite launches into space, the students have gained invaluable experience.

Twiggs has already seen the effects of the hands-on education on former students. One was instrumental in creating the groundbreaking Dragon spacecraft for private spaceship-maker SpaceX. Meanwhile, Skybox Imaging, a satellite company created by former students of Twiggs, was recently bought by Google for $500 million.

THE FINAL FRONTIER

The next generation of CubeSat students will get their satellites into space even more efficiently, as improving technology makes launches economically and environmentally easier. DARPA, Virgin Galactic and others are working on experimental new orbital launches that use airplanes to get to the edge of space.

The satellites themselves are also becoming more robust, with parts that can withstand higher altitudes and last longer. NASA hopes to launch 11 CubeSats where they've never gone before, into deep space, through the maiden mission of its Space Launch System, NASA's most powerful rocket ever. One of these satellites, the Lunar Flashlight, will study the moon's resources with the hope that future explorers might one day exploit them for building materials, drinking water or even oxygen. Another of the 11, the BioSentinel satellite, will use yeast to determine the effect of deep-space radiation on living organisms.

"We've been able to see the whole growth of an industry, growth of components, and such well-educated students that they are joining the ranks of these new aerospace companies and NASA," says NASA's Crusan. "And now we're actually going to go out and execute some exploration missions, using these small satellites." Pretty impressive for an overgrown science experiment that fits in your hands. D

Caroline Barlott *is a freelance writer whose work has appeared in* Reader's Digest, Canadian Geographic *and* Avenue Edmonton.

My Own Worst Enemy

Why we act against our better judgment.

BY **CHRISTIE ASCHWANDEN**

I get a little pain in my knee when I walk down stairs or run long distances. The problem has gotten worse with age but has an easy fix — a short series of strength exercises. If I do them a few times per week, I'm pain-free.

The routine takes only about 15 minutes, and I can do it at home. Even so, I just can't seem to make it a habit. I tell myself I'll do it at the end of my workday, but when 5:30 p.m. rolls around, I often find myself unwinding with a run or a beer instead. "I'll do the damn exercises tomorrow," I promise myself. But the pattern repeats itself the next day, and often the next, sometimes until my knee starts hurting again.

Greek philosophers have a word for this behavior: akrasia, the state of acting against one's better judgment.

While akrasia is sometimes called "weakness of will," recent research suggests that it's not a personal failing, but a result of a cognitive bias that strike us all — "time inconsistency," our tendency to discount the future in favor of the present.

George Ainslie, a psychiatrist at the Veterans Affairs Medical Center in Coatesville, Penn., and behavioral economist at the University of Cape Town in South Africa, has spent decades studying akrasia. He's found that if you give people a choice between a smaller, more expedient reward and a larger delayed one, timing has an interesting impact on their decisions.

"If you pretend it's a game show and you offer people $50 today or $100 in two years, when you ask how many people would prefer $50 today, a lot of people raise their hands," Ainslie says.

But if people can choose between receiving $50 in six years or $100 in eight years, nobody wants the $50, he says, even though it's the same choice, just spread over a different time period. Such results show that people discount the future in an inconsistent way that gives preference to smaller, more immediate rewards, Ainslie says.

I choose happy hour over my knee-strengthening exercises because the pleasure of beer is immediate, while the pain I'll prevent with my gym routine isn't.

BATTLE OF THE SELVES

"We all do it; it's part of our nature," says Piers Steel, a psychologist at the University of Calgary and a leading researcher on one of akrasia's most common manifestations: procrastination.

Long-term planning, such as saving for retirement or committing to an exercise plan, is done in the brain's prefrontal cortex. "Then we have the limbic system," Steel says, "which is much more compulsive and focused on the here and now." One way to see it, he says, is to think of our brain as a house with two floors, each with a

MERIEL JANE WAISSMAN/ISTOCK

different set of residents. The limbic system is the young, hip couple on the ground floor who are "energetic and passionate, and focused on the present," he says. Meanwhile, the prefrontal cortex is the older couple upstairs who pay the mortgage and keep the house in order.

Akrasia is essentially a one-player game against your future self, says Daniel Reeves, who applied his Ph.D. in algorithmic game theory to co-found Beeminder.com, an anti-akrasia tool. For example, my present limbic system-influenced self would rather surf the Internet than write this story. But my future prefrontal cortex-influenced self would rather finish the story so my check arrives on time. To overcome akrasia means to ensure the future-oriented self overrides the present-oriented one, Reeves says.

A handful of tools exist to help bridge the gap between your future and present selves. Such tools create an immediate payoff for desired behavior and a short-term punishment for choices that derail long-term plans.

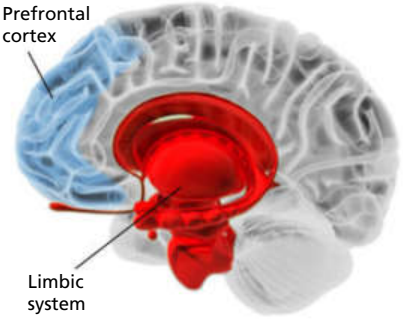
For instance, when I record my knee exercises on Beeminder, I'm more motivated to stay on track because logging a completed knee-strengthening session makes me feel productive and helps me avoid the unpleasant feeling of having nothing to report when the app sends a reminder.

As an extra incentive, Beeminder and another online goal-tracking tool, Stickk.com, charge users money if they don't complete their goals.

Along the same lines, Habitica.com turns habit-tracking into a video game by representing each of your goals as monsters that you're on a quest to conquer.

Even banks are jumping on the anti-akrasia bandwagon. A series of studies published in the *Journal of Marketing Research* in 2011 found that participants who saw computer renderings of their future selves tended to pick monetary rewards promised later instead of picking more immediate ones. Financial company Merrill Lynch took a cue from these findings and has a project underway to motivate people to save more retirement money by showing them digitally aged photos of themselves.

CLAUS LUNAU/SCIENCE SOURCE



Long-term planning happens in the brain's prefrontal cortex, while the more compulsive limbic system focuses on things that provide immediate gratification.

My present limbic system-influenced self would rather surf the Internet than write this story. But my future prefrontal cortex-influenced self would rather finish the story so my check arrives on time.

FIGHTING TEMPTATION

Steel argues that our modern environments have made us more susceptible to akrasia. "We're not really designed to have temptation constantly at our fingertips," he says. Those of us who work on computers know this all too well: The Internet ensures we have time-sucking distractions constantly competing for our attention. And since the 1970s, researchers have "seen about a 500 percent increase in chronic procrastination," Steel says. So if we really want to tame akrasia, we need to change our environment.

"You never want the same cues for play and for work," he says, because if you set yourself up to choose between play and work, play always feels more enticing.

When I use the end of my workday as the cue for doing my knee-strengthening routine, I'm pitting it against more tempting choices. Of course I'll choose a relaxing drink on the front porch over a boring workout in the home gym. But when I shift my cue to the morning before I start my workday, it's easier to stick to my good intentions. That's because the gym, where I can listen to music or my favorite podcasts, feels more alluring than the alternative: work.

It's a clever solution, but it's not always possible. Some days, I need to get to work early and don't have time for my strengthening routine. In that case, I've found success with another trick from Steel: delay. "Sometimes just a minute or two delay of the temptation makes you far more likely to make a rational choice," he says. He's currently experimenting with computer programs that add a delay before users can access common distractions. "You can get your email, but you have to wait 20 seconds," Steel says. So far, the results show that even a short 20-second delay can help people make better choices.

And that strategy is working for me, too. Doing my exercises after work is much easier after I decide that, if I skip them, I can't do anything else during those 15 minutes. As much as I hate the exercises, I like them better than doing nothing. So, off I go to do the damn exercises now so I can run pain-free later. D

Christie Aschwanden *is the lead science writer at FiveThirtyEight and a health columnist for* The Washington Post.

Playing the Odds

An athletic woman in her 50s suddenly can't move her arm, then feels fine several minutes later. But an MRI reveals serious trouble elsewhere.

BY **TONY DAJER**

"But can I still go to the Virgin Islands?"

Ellen, 51, vivacious and trim, looked the perfect candidate for some fun in the sun.

"I feel fine. It was only a minute or two," she said.

"I'm sure you're OK," I said. "But better to do all the tests quickly in the hospital and start treatment."

"I do everything right." She ticked off her fingers, "I work out. I quit smoking. I even skip birthday cake!"

"The CT scan and your lab work look good so far."

"Do I really need to stay overnight?"

I held her shoulder. "We'll get the MRI in a few minutes, then we need some heart tests. It would make me much happier if you stayed."

It started with a phone call. "Couldn't move her arm." It was my good friend Bill. Ex-ER doc, now in-house company physician, he is a master at plucking rare needles of disease from a haystack of healthy young people.

"How long?" I asked.

"That's the funny thing. Yesterday she was getting ready for the gym, then couldn't move her arm. Thought maybe she'd slept on it funny, but realized it had been fine when she woke up. After a minute or so, the strength came back. Today she decided to see me. Right now she could do 30 push-ups."

My alarm bells went off. "Send her in."

"I know," he answered. We both suspected TIA, a transient ischemic attack, or ministroke. "But to where?"

I rang Dr. Redder, our chief neurologist. "My office is all booked up," she said. "But ER's better anyway. I can monitor her while we get everything done." I relayed that to Bill. "Tell her to ask for me."

DEALING IN DILEMMAS

TIAs are the devil's work — red flags that pop up then vanish. Mechanically, they are simple: just block any blood vessel in the brain for a few minutes. Clinically, they make doctors crazy, unleashing a cascade of what-are-the-odds dilemmas: Was that momentary hand weakness a TIA or a carpal tunnel flare? That spell of vertigo an inner-ear misfire or a clot to the cerebellum? That blurred vision a blocked retinal artery or a migraine?

By definition, TIA usually means by the time you see the patient, all appears normal, like someone crying, "Look! A shooting star!" But you look up and behold only night sky.

Up to 1 in 10 TIAs will progress to a full-blown stroke within 48 hours.

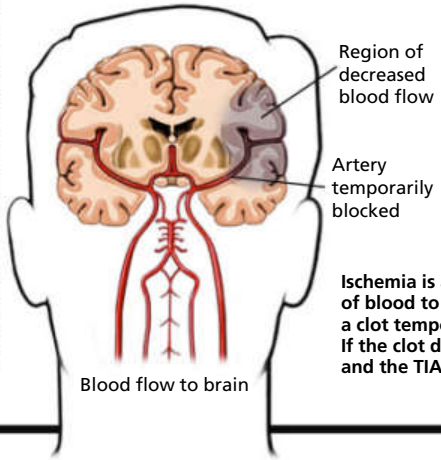
TIAs can be thrombotic or embolic, arising from clots formed in a brain artery diseased with atherosclerotic plaque, or from clots traveling to the brain from the heart or arteries upstream. If the body's clot-dissolving system chews up the wayward clots before neurons die, then it's a TIA. If not, it's a stroke.

Why the urgency to test Ellen? Because up to 1 in 10 TIAs will progress to a full-blown stroke within 48 hours. The good news is that these odds can be slashed through prompt treatment with aspirin or blood thinners, surgery for blocked carotids, statins for high cholesterol, regimens for smoking cessation and meds for blood pressure control. The tempting counterbet? Up to two-fifths of TIA patients may never have another. But no one knows *which* two-fifths.

Dr. Redder came by. Compact and wicked smart, she pulled me aside.

"The MRI is *not* normal. Scattered white-matter microinfarcts. She's been showering small clots for a while. Probably from the heart."

White matter is the layer just beneath the brain's surface neurons (imaginatively called "gray matter"). The specks of damage were so small, Ellen probably hadn't sensed them. But they drew an ominous pattern.



Ischemia is a medical term describing insufficient supply of blood to an organ. In a transient ischemic attack (TIA), a clot temporarily interrupts blood flow in the brain. If the clot does not dissolve in time, neurons die, and the TIA progresses to a full-blown stroke.

TOP: LEONELLO CALVETTI/SCIENCE PHOTO LIBRARY/CORBIS. BOTTOM: NUCLEUS MEDICAL ART INC./PHOTOTAKE

gravity defyer®
COMFORT FOOTWEAR TECHNOLOGY

Scientifically ENGINEERED to DEFY GRAVITY

G-DEFY
GAMMA RAY

"They are awesome, saved my job… I work on my feet all day and used to pack my knees with ice, now I come home with no pain."
– Ron B.

VersoShock *Patented Technology In Every Step*

PROTECTION	COMFORT	PERFORMANCE
Absorbs Harmful Impact	Stores Energy, Distributes Force	Returns Energy

- ✓ **Absorb harmful impact**
- ✓ **Stay comfortable & active**
- ✓ **Support & protect your body**
- ✓ **Stand & walk with greater ease**

WIDE WIDTH AVAILABLE X-WIDE WIDTH AVAILABLE

Feel better. Do more.

The stress and discomfort of being active and on your feet can destroy your quality of life. As you age, cartilage and other tissues that protect your joints become thinner and less resilient. Gravity Defyer® footwear helps protect your body and provide shock absorption from the ground up. Jogging, running, walking – even routine standing, generate punishing impact. These forces produce lasting damage and wear on the body. Gravity Defyer footwear changes how our bodies relate to the forces that prevent us from leading more active lives.

The Ultimate Shock Absorbing Footwear

With each step our patented shoe technology returns energy to you, to help you stay active and on your feet longer. A more active you means your muscles build strength and endurance, your body receives more oxygen and nutrients, and the heart and lungs work more efficiently. As your body gets more efficient you will have more energy to live the life you've always dreamed of!

Gamma Ray $145
MEN · SIZES 7.5-15
MEDIUM & WIDE WIDTHS

- BLACK TB9016MBB — MED/WIDE X-WIDE
- WHITE TB9016MWS — MED/WIDE
- BLUE TB9016MUL — MEDIUM

WOMEN · SIZES 5-11
MEDIUM & WIDE WIDTHS

- BLK/PURP TB9016FLP — MED/WIDE
- GRAY/RED TB9016FRI — MED/WIDE
- WHT/BLUE TB9016FWU — MEDIUM

$30 OFF YOUR ORDER
PLUS
FREE SHIPPING ON ORDERS OVER $125
Free Exchanges • Easy Returns

COUPON CODE: MB2LGZ9
Call **1 (800) 429-0039**
GravityDefyer.com/MB2LGZ9

Gravity Defyer Corp.
10643 Glenoaks Blvd
Pacoima, CA 91331

* Payment options and terms available at checkout. Credit or debit accepted. Shoes must be returned within 30 days in like-new condition for full refund or exchange. Credit card authorization required. See website for complete details. Free shipping on orders over $125 in the United States.

Dr. Redder went back to Ellen.

"The MRI shows you've probably had similar events in the past. It's very important we investigate where they're coming from."

Ellen took the news quietly. After Dr. Redder left, I added, "In healthy people under 55 with a TIA, we don't always find a clear explanation. But now I'm sure you need to stay."

"What will I tell my family?"

"That we're not sure yet."

The next morning, I spied Dr. Redder and a cardiologist talking animatedly in the hallway.

"What?" I asked.

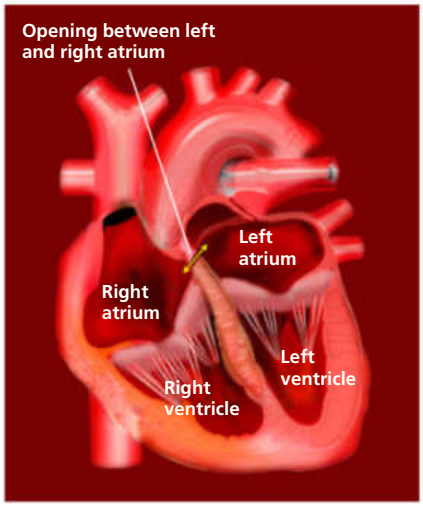
"TEE showed a *big* PFO," she said. Translation: An echocardiogram showed a hole in Ellen's heart. Or more accurately, a flap.

A FAILURE OF FUSION

From a developmental perspective, our four-chambered heart (the right atrium and ventricle pump venous blood to the lungs; their more powerful counterparts on the left side pump oxygenated blood to the body) is a surprisingly jury-rigged machine. In utero, it must shunt oxygenated placental blood from right atrium to left to bypass the fluid-filled lungs. When a baby's born, its most critical mission is to switch from underwater to air breathing. Part of that transition includes sealing right atrium from left.

The human heart's brick-laying is intricate: Early in fetal life, a wall is built between the atria that leaves an opening at the top. Later, a stronger second wall forms on the right atrium side that also leaves a hole, but at the bottom. Placental blood can still flow from right to left, with the first half-wall acting as a one-way flap for the hole in the second (think two overlapping playing cards). With a baby's first breath, the lungs open and pull in right atrium blood; pressure there drops while it rises in the left atrium, thus pushing the flap against the hole. By age 2, over 70 percent of people fuse both partial walls into one.

The specks of damage were so small, Ellen probably hadn't sensed them. But they drew an ominous pattern.



In a patent foramen ovale (PFO), a flap between the two upper chambers of the heart allows venous blood to mix with oxygenated blood. If the blood crossing over contains clots, these can travel up the carotid artery to the brain.

Those who don't fuse end up with a PFO, or patent foramen ovale. The risk is this: Small clots can arise in leg veins with prolonged sitting or inactivity. Venous blood returns to the right atrium, then to the right ventricle, which pumps it through the lungs. Happily, the lungs can filter out small clots with minimal harm, but the brain — where each patch of neurons has a specific function — is less forgiving. If a small clot crosses from right atrium to left — a so-called paradoxical embolus — the left ventricle might send it up the carotid artery and paralyze your arm. Studies show that a significant amount of PFOs allow venous blood across while a person is at rest — almost all do if you boost right-heart pressure with actions like bearing down or coughing.

TREATMENT IS NOT CLEAR-CUT

So what were the odds a PFO caused Ellen's TIA?

Cryptogenic strokes — those lacking known causes like a blocked carotid or heart arrhythmias like atrial fibrillation that spawn clots — comprise almost half of strokes in patients under 55. In such patients, PFOs are more common (39 percent compared with 26 percent) and bigger than in the general population.

The usual treatment for any cryptogenic TIA or stroke is cholesterol and blood pressure reduction, if indicated, plus an anti-platelet agent, like aspirin. Studies have tested whether closing PFOs with umbrella-like devices introduced into the right atrium via the femoral vein would help. The procedure showed no additional benefit, but some experts believe it could if medications don't hold the line.

"I have a hole in my heart?" Ellen exclaimed when we told her. "It's been there my whole life?"

"One in four people do to some extent," I reassured her. "We can't be sure the PFO caused your TIA, but the MRI suggests tiny clots have sneaked across before."

The size of Ellen's PFO and the MRI pattern led the cardiologist to add Plavix, another potent anti-platelet drug, to the aspirin.

Since then, Ellen has found that she doesn't like taking so much medicine and worrying about the risk of bleeding. The closure procedure, despite its small chance of causing a stroke itself, is looking more attractive to her. She'll always have to weigh the odds.

But I'm pleased to report she did make it to the Virgin Islands. D

Tony Dajer *is director of the emergency department at New York-Presbyterian/Lower Manhattan Hospital. The cases described in Vital Signs are real, but names and certain details have been changed.*

CAROL AND MIKE WERNER/PHOTOTAKE

The most expensive Mercedes-Benz® ever made. Rarer than a Stradivarius violin.

Not actual size.
Shown is model in Pearl White finish.
Also available in Ruby Red finish.

How to Park $11.7 Million on Your Desktop

The 500K Special Roadster is one of the rarest and most-sought after automobiles ever built.

It's hard to deny that one of the signature models of Mercedes-Benz® is the 500 series. So many striking and elegant bodies would grace the stalwart chassis. The 500K's of the 1930s were beautiful, elegant, and exclusive models often outfitted with voluptuous coachwork and sold to the wealthiest of clientele.

The most ravishing model of this species was the two-seater 500K Special Roadster launched in 1936. It was a limited production cabriolet, in total less than 30 were made, adding to its near-mythical qualities. In its day it went for top dollar—over $106,000. Today, these ultra rare masterpieces are going for millions. **In 2012, a Special Roadster fetched more than $11.7 million at auction at the Pebble Beach Concours d'Elegance.**

Die-cast metal body features doors, hood and trunk that open, steerable wheels that roll, and four wheel suspension. Available in Ruby Red finish.

Forgo the bidding wars, nail-biting flatbed transport, and scavenger hunting for parts in Germany. Here's your chance to own the rare and luxurious essence of this remarkable car in terms of its unforgettable styling, inimitably powerful and elegant lines, and showstopping presence.

Our die-cast metal replica captures the sexy curves and sumptuous coachwork of the full-size model in striking detail. Just shy of a foot long, and available in pearl white or ruby red.

You don't need to spend millions to showcase your impeccable taste. Sold! To the discerning reader for $99!

Your satisfaction is 100% guaranteed. Test drive the Special Roadster for 30 days. If for any reason you are not completely satisfied, simply return it to us for a full refund of your purchase price. But we're sure that once you park this beauty in your house you'll be sold.

Comes factory sealed in its original packaging in order to retain its status as a highly collectable item.

1936 Mercedes-Benz® 500K Special Roadster
(Pearl White or Ruby Red finish) ~~$149~~†

Offer Code Price **$99** + S&P Save $50

1-888-201-7081

Your Insider Offer Code: MBD212-01
You must use this insider offer code to get our special price.

† Special price only for customers using the offer code versus the price on Stauer.com without your offer code.

Stauer®
14101 Southcross Drive W.,
Dept. MBD212-01
Burnsville, Minnesota 55337
www.stauer.com

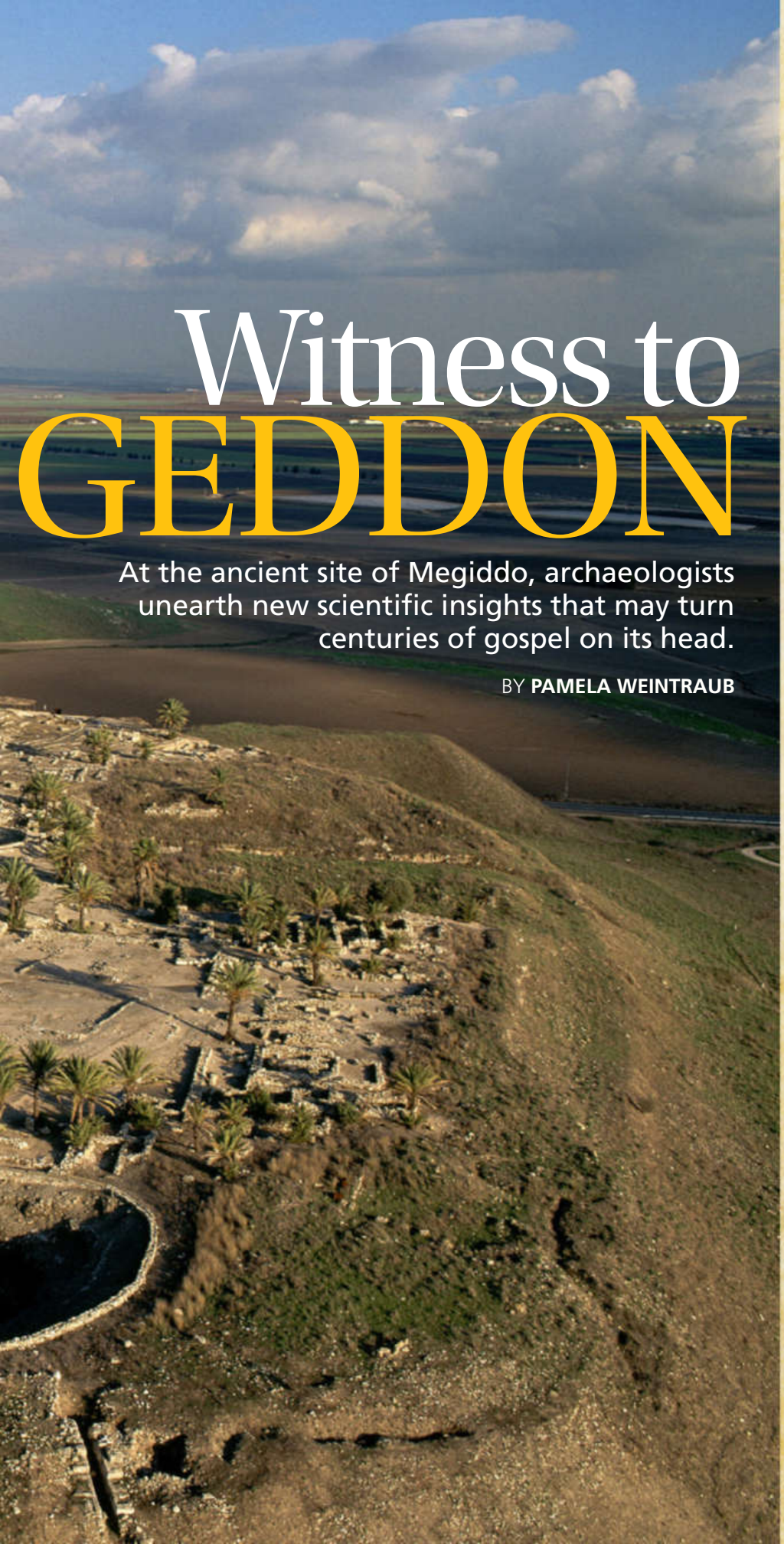
ACCREDITED BUSINESS
Rating of A+

High-quality 1:18 scale die-cast replica • intricate moving features • Detailed chassis with separate exhaust systems • Includes display stand

Smart Luxuries—Surprising Prices™

ARMA

The Tel Megiddo archaeological site in Israel overlooks areas that have biblical significance, including the Jezreel Valley and, at the far left, Mount Tabor.



Witness to GEDDON

At the ancient site of Megiddo, archaeologists unearth new scientific insights that may turn centuries of gospel on its head.

BY **PAMELA WEINTRAUB**

DUBY TAL/ALBATROSS/ISRAELIMAGES.COM

Driving north to Tel Megiddo, I am traveling back in time. Receding behind me, the Wi-Fi cafe culture of Tel Aviv, the white city on the beach. Looming ahead, Highway 6, tracing the Via Maris, the major trade route of the ancient world. Stretching from Egypt to Mesopotamia (present-day Iraq), the road passed the overlook city, Megiddo, making the community atop the mound a player in the history of wars and men.

One of the most embattled sites of antiquity, Megiddo has another name: Armageddon, the place the book of Revelation says we will savage each other in the last days of Earth.

Back in Tel Aviv, sirens will soon be sounding, the Iron Dome defense system blasting missiles out of the sky. Atop Tel Megiddo, I'll mainly hear wind and doves. The contrast is deceptive: Beneath the dusty mound, or tel, are at least 20 layered cities destroyed by war, by fire, now densely packed and superbly preserved through millennia.

Commanding an army of workers bearing chisels and brushes, the iconoclastic Israel Finkelstein, a Tel Aviv University archaeologist and director of the Megiddo Expedition, orchestrates an upheaval of his own: By opening the belly of Megiddo, he is challenging the narrative of the Bible, upending ancient Israeli history and derailing what we thought we knew

about the Iron Age in this region called the Levant.

Much of the uproar concerns a long-standing fight over David and Solomon, the legendary Iron Age kings. The father and son duo likely ruled some 3,000 years ago, between 1010 and 931 B.C., but the extent of their power and kingdom has been subject to fierce dispute. Were they, as the Bible says, powerful monarchs of a united, monumental Israel, stretching from Beersheba in the south to Samaria in the north? Or were they petty chieftains commanding a ragtag band of hundreds — their capital city, Jerusalem, an outpost so hardscrabble it lacked even a blacksmith to shoe a horse?

The answers are important because the palaces and chariot cities historically considered the kings' legacy might have been built by other leaders and groups in other times. The reallocation of credit could alter whose version of history — secular or religious, Jewish, Christian or Muslim, one school of archaeology or the other — rings most true in this turbulent land. And there is much at stake.

SCIENCE AND SCRIPTURE

The week I arrive atop the tel, the bodies of three kidnapped Israeli boys are found in a West Bank field, just the latest gruesome installment of homicidal hatreds tied to contested ownership of Israel. The battle over antiquity dovetails with the war that has persisted through modern times.

To settle the debate, Finkelstein has brought a new method to biblical archaeology. For years, archaeologists investigating the time of the Bible worked with the text in one hand and a trowel in the other, hoping to confirm Scripture. "In the beginning there was the Word," the Bible says, and archaeologists sought to prove that it was gospel.

Convinced this circular logic wasn't providing satisfactory results,

Armageddon's Greatest Hits

Standing atop Tel Megiddo, George Washington University archaeologist and military historian Eric Cline, the dig's former co-director, overlooks a panorama of biblical and violent lore. "Over there, to the left, is Mount Carmel, where Elijah the prophet is said to have pitted the Hebrew God, Yahweh, against the idols of the Canaanites, provoking the fall of a dynasty in the ninth century B.C.," he says. To the right, he points out Mount Tabor, where Deborah, mentioned in the Old Testament's book of Judges, calls on her general, Barak, to lead an Israelite army 10,000 strong in about the 12th century B.C. He then traces the strategic route taken by Pharaoh Thutmose III's army when it marched right up to Megiddo, engaging the Canaanites in the first recorded battle in the history of the world, in the 15th century B.C.

"This area has always been a theater of war," says Cline. The armies of the Greeks, the Romans and the Crusaders fought here. In 1799, Napoleon fought near here, calling it "the most natural battleground of the whole Earth."

And the battles didn't end there. In a recent excavation, Cline stumbled upon more than 200 spent cartridge cases from the most modern Megiddo battle: the Arab-Israeli War of 1948.

A student of war at Armageddon, Cline offers up his list of the greatest battles, real and literary, and yet to come. — PW

12th century B.C. Moses' general, Joshua, is said to emerge from the Sinai to capture the land of Canaan. The Bible says that among his victories, he defeated the king of Megiddo — the tel would be on anyone's list of must-haves for controlling the ancient world.

1479 B.C. Pharaoh Thutmose III successfully marches on Canaanite Megiddo, taking what was considered the most dangerous route: a narrow mountain path easily susceptible to ambush.

12th century B.C. The biblical prophet Deborah asks her general, Barak, to marshal an Israelite army of 10,000 to defeat the Canaanite forces of King Jabin. The battle, which they won, was said to be fought near Megiddo.

925 B.C. Egyptian Pharaoh Sheshonq attacks Megiddo, an event well-documented in extrabiblical sources, though due to sloppy archaeology, people are still confused about which layer of the tel, precisely, was attacked. A stone slab documenting his presence was found in a trench in the 20th century.

732 B.C. Assyrians attack Megiddo, driving Jewish residents of the northern kingdom south to Jerusalem, causing the city's population to swell.

LEFT: SANDRO VANNINI/CORBIS. RIGHT: DANITA DELIMONT/GETTY IMAGES

Finkelstein pioneered another way forward: using science, and science alone, to shed light on antiquity, regardless of what the Bible might say. Toward that end, he wields the revolutionary tools of microarchaeology — the reconstruction of history from elements invisible to the eye. Sophisticated carbon dating helps narrow in on the age of organic materials found in ancient ovens. Magnetic fields generated by Earth's core leave time stamps on pottery. Ancient DNA can track the movement and overthrow of peoples.

"We can tell which wall fell first in a battle and whether it fell by fire or force," Finkelstein says. The clarity this can bring to the dig is astonishing. Most archaeologists have deciphered history in 200-year increments, but Finkelstein now can narrow construction, destruction and other events in antiquity to within as little as three decades, helping him refine the archaeological clock.

TALES OF HEROES

For families like Finkelstein's, Palestine was all about pushing the reset button: One set of Finkelstein great-grandparents, from Belarus, helped establish the region's first proto-Zionist agricultural settlement in 1878 in Petah Tikva, today a working-class neighbor of Tel Aviv. Another set, fleeing the Bolsheviks, came to farm the same land around 1920. Born in 1949, Finkelstein grew up in the family compound among orange growers and packers, in a "totally secular atmosphere, but very warm and sweet."

The family resembled other Ashkenazi Jews fleeing pogroms and later the Holocaust, set on validating their roots and reclaiming their ancient, storied home. But with many Ashkenazi so blond and light-eyed — so *European*-looking — it was hard to stake their homeland claim on appearance alone. Instead, to create a narrative for

609 B.C. Josiah is killed at Megiddo by Pharaoh Neco of Egypt after the pharaoh warns him to stay away — at least according to the Bible. His death is the first step in the downfall of Israel, ending with the destruction of Solomon's Temple on the Mount in Jerusalem.

A.D. 1099 The first Crusaders arrive in the Holy Land, hoping to recapture it for Christianity. Starting in **1113**, Maudud of Mosul and other Muslims launch a series of campaigns to retake their territory. Armies of Crusaders and counter-raiders roam the land, including the area around the Jezreel Valley and Mount Tabor, near Megiddo, until **1260**, when Egyptians retake the area for good.

1799 Napoleon faces the Ottomans in the Jezreel Valley, scattering them to the winds and calling the Megiddo valley the most natural battleground on Earth.

1918 The Battle of Megiddo, the final Allied offensive of the Sinai and Palestine campaign at the end of World War I. As part of the strategy there, British Gen. Edmund H.H. Allenby takes a page from history, defying orders and following Pharaoh Thutmose III's path right down the center of the Jezreel Valley, evading detection until he reached the tel.

Armageddon
The penultimate battle to rock us before the end of the world is supposed to take place on the dusty mound, Megiddo. Date unknown.

FROM TOP: UNIVERSAL HISTORY ARCHIVE/UIG/GETTY IMAGES; CORBIS; PRISMA/UIG/GETTY IMAGES. MAP: JAY SMITH

the nation they hoped to build, the founders zoomed in on archaeology. Science would authorize their Bible, their legacy and their right to the land.

The most eloquent messenger was Hebrew University archaeologist Yigael Yadin, known for his excavation of Masada, the desert fortress described as a scene of a shameful mass murder-suicide after a failed revolt. By the time the dig ended in 1964, Yadin had transformed the events into a tale of heroic resistance. Chief of staff of the Israel Defense Forces before he became

Israel Finkelstein, an archaeologist at Tel Aviv University, has championed microarchaeology methods at Megiddo since the early 1990s.

an archaeologist, Yadin had used his new field to pump up the volume on Israel's ancient roots, warrior spirit and right to exist.

For Yadin, the story went back to the Exodus of Jewish slaves from Egypt, when Moses' general, Joshua, was said to storm the land of Canaan and take it by force. That was the Bible story that Finkelstein, still a graduate student, found himself revisiting in the 1970s on assignment in the highlands, a mountainous ridge running almost the length of Israel. There, archaeologists had dated the earliest settlements of the Hebrews — recognized by the lack of pig bones, reflecting their pork taboo — to perhaps the 13th century B.C. Had these people really been slaves in Egypt, returning as invaders as Yadin put forth? Finkelstein found otherwise. Instead of an invasion, the archaeological evidence revealed a gradual evolution from a pastoral to an agricultural society. "There was no violent event, no entry from the outside, not one suggestion of the Exodus. The Hebrews *were* the Canaanites, who had never left."

A STORY IN QUESTION

Finkelstein the skeptic discovered microarchaeology for himself at Shiloh, a biblical-era city in today's West Bank. There, in the 1980s, he set out to retrace the construction of a solid ancient fort that appeared to have no apparent way for water to drain.

"Without drainage, the whole thing would have gone kaput," notes Finkelstein. Yet 4,000 years later, here it stood. Finkelstein recruited a soil expert, who found chemically distinct, porous building material just where the water should flow. "Maybe they didn't know to call it limestone," Finkelstein realized, "but they knew how it would function in the wall."

Microscopic analysis of the ancient wall opened Finkelstein's eyes, and by 1990 he hoped to shine the same scientific light on the biggest of the big questions: the enduring mystery of the reigns of David and Solomon. Logically, the best place to search was under modern Jerusalem's Temple Mount — also a tel, upon which much of the ancient city was built. But the site currently hosts the Dome of the Rock and the Al-Aqsa Mosque, two of the most sacred places of Muslim prayer, making excavation tantamount to an act of war.

Getting around the problem, Yadin searched for the footprints of David and Solomon further afield, tapping a biblical passage from 1 Kings:

> *"And this is the account of the forced labor which King Solomon levied to build the house of the Lord and his own house and the Millo and the wall of Jerusalem and Hazor and Megiddo and Gezer."*

The verse describes Solomon's grandiose building projects, including a huge stepped-stone structure called the

A Layering of Cities

Israel Finkelstein used micro-archaeology to find any trace of David and Solomon's kingdoms within a slice of six partially dated cities, stacked below, atop and inside Tel Megiddo. The site, pictured right, is divided into specific areas of excavation.

Assyrian city built after invasion in 732 B.C. caps the tel's Iron Age layers.

Monumental Israelite city, notable for a massive wall and two pillared buildings, widely considered stables. Built by the Omrides of the north.

Finished-stone ashlar palaces and other structures of high civilization are woven through Yigael Yadin's Solomonic tales. Finkelstein also identified it as belonging to the Omride Dynasty.

A slum so crudely wrought, its builders did not even bother to clear the rubble.

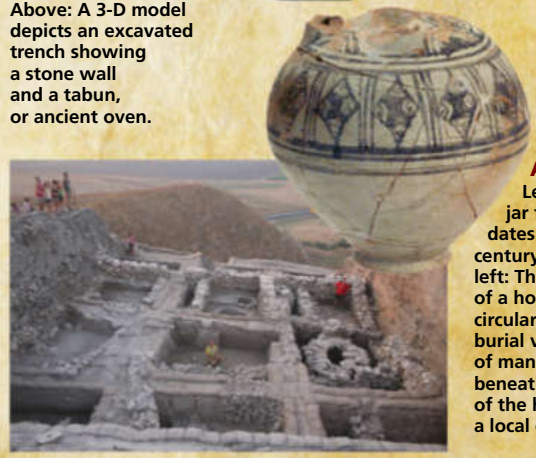
Red burnt brick city. This rich cosmopolitan world represented the last of Canaanite culture. It existed right before the rise of the Hebrews and was recognizable across the tel because a great conflagration turned it red. Skeletons and treasures resting in place attested that no one had time to run. No one knows how the devastation happened.

City destroyed in a general Bronze Age collapse in the 12th century B.C.

COURTESY OF ISRAEL FINKELSTEIN

Area L
Above: A team stands in Palace 6000, one of the ashlar palaces, originally excavated in the 1960s by Israeli archaeologist Yigael Yadin.

Area Q
Above: A 3-D model depicts an excavated trench showing a stone wall and a tabun, or ancient oven.



Area K
Left: A stirrup jar from the site dates to the 11th century B.C. Lower left: The excavation of a home reveals a circular stone family burial vault, one of many installed beneath the floors of the house — a local custom.

Area H
Above: A Megiddo Expedition member works near shattered pottery from the red burnt brick city. Left: A ceramic stand excavated from the site dates to the eighth century B.C.

Area J
Right: In the deeper section, two of three rectangular temples date to the Early Bronze III period, 2600 to 2500 B.C. The site includes remains of a huge Early Bronze I period temple, the earliest example of the urbanization process in the area.

CLOCKWISE FROM TOP: HANAN ISACHAR/ALAMY; ADAM PRINS, THE MEGIDDO EXPEDITION/TEL AVIV UNIVERSITY (6)

German archaeologist Gottlieb Schumacher stands near the corbel arch of a burial chamber at Megiddo in 1905.

An ivory box decorated in high relief with lions and sphinxes was excavated at Megiddo. It dates to between the 13th and 12th centuries B.C.

A fragment of a 10th-century B.C. slab inscribed by Pharaoh Sheshonq was unwittingly tossed into a trench by Schumacher. It was found in 1926 during excavations at Megiddo by a University of Chicago team.

Millo — still prominent below today's Temple Mount in Jerusalem — and massive, nearly identical six-chambered city gates at Jerusalem, Megiddo and two other tels.

Every morning the verse greets us near the entry to Megiddo, where it adorns a plaque. Finkelstein stops to read the words with irreverent scorn. The verse was written 300 years after Solomon's death, during the reign of his descendant, Josiah, a man with a nation-building agenda and plenty of motivation to make ancestral claims for monumental achievements and land.

"Someone sitting in Jerusalem cooked these words up at the end of the seventh century B.C., so how did they know what really happened centuries before, in the 10th century B.C.?" Finkelstein says.

A TIMELINE IN QUESTION

If you accept the biblical timeline on faith, you could be throwing actual history out of kilter for centuries. If the gates at Megiddo were built during Solomon's reign between 970 and 931 B.C., then any structures found in layers directly above those gates are bound to be ninth century B.C.; structures buried directly below the gates would, de facto, be 11th century B.C., and so on. Because the accepted historical timeline hinges on just one Bible passage, our concept of what happened — and when — could be completely off.

The disarray was obvious to Finkelstein the moment he arrived atop the 15-acre expanse of Tel Megiddo in 1992. Standing above a slope at the southern part of the tel, he surveyed the handiwork left by archaeologists whose labors were well intentioned for the time but whose technologies were crude compared with modern techniques.

From 1903 to 1905, German archaeologist Gottlieb Schumacher cut a deep trench through the site, tossing anything he deemed unimportant into a pit. That's where he unwittingly threw a slab inscribed by Pharaoh Sheshonq, known to have captured Megiddo in 925 B.C. But with the slab in a ditch, no one knew which buried city — which layer of the tel — was actually attacked.

Then, from 1925 through 1939, a University of Chicago team peeled off layers of the tel, dumping entire cities into landfills, where once-valuable artifacts were now entirely out of context. That's where Finkelstein found the remains of an ashlar palace, so-called because the stones are regular, beveled and finely cut as opposed to the more usual irregular "rubble" used to make buildings of the time. The palace was supposedly commissioned by Solomon in the mid-10th century B.C.

However, the stones held a "mason's mark," an engraved branding pattern, identical to those on ashlar blocks at the later ninth-century B.C. ruins of Samaria, the capital of a second Hebrew kingdom to the north. "Either you explain this find or you have to push the dates forward a century," past the time when Solomon lived, Finkelstein says.

For years, Finkelstein discussed his concerns only with friends, but in 1996 he laid out his thoughts in the journal *Levant*. To help frame the question about the kings, he anchored his timeline with two Megiddo cities with precise dates already established from sources outside the Bible.

The first anchor, closer to the bottom of the tel and more distant in time, was a vast, wrecked city swept away by a regionwide collapse of society at the end of the Bronze Age, in the 12th century B.C. The second anchor, some 400 years later and today sitting on the surface of the tel, was a city built by the Assyrians after their well-documented invasion in the eighth century B.C.

Four sequential cities with indeterminate dates were sandwiched between: Right on top of the Bronze Age destruction was a cosmopolitan world that represented the last of Canaanite culture, called the "red brick city," which burned to the ground. Above that Canaanite city was a crude slum. Higher still, Finkelstein could see a monumental city with two

FROM LEFT: MEGIDDO EXPEDITION/TEL AVIV UNIVERSITY; APXAIOC INSTITUTE/INSTAGRAM@APXAIOC/WWW.FACEBOOK.COM/APXAIOC; BIBLELANDPICTURES.COM/ALAMY

Left: A model of Tel Megiddo shows the city during the Iron Age, including substantial gates to the city on the far right. Below: An ivory plaque from Megiddo depicts a ruler sitting on a throne. It dates from between the 13th and 12th centuries B.C.

Left: A decorated Canaanite pottery stand, used for holding a bowl to burn incense, dates to the 11th century B.C.

FROM LEFT: BIBLELANDPICTURES.COM/ALAMY; ANTONELLA865/MEGIDDO MUSEUM PHOTO/DREAMSTIME.COM; BIBLELANDPICTURES.COM/ALAMY

ashlar palaces. And directly above that (and right under the Assyrians) sat a chariot city with stables for horses. Inside these four layers, Finkelstein would seek the kings.

For boosters of David and Solomon, things did not look good. Even Yadin agreed the stables were built by the northern kingdom of Israel long after Solomon had roamed the Earth. And Harvard scientists dated an assemblage of nearby pots on the same level as the ashlar palaces to the ninth century B.C., a hundred years after the kings were said to reign, leaving the duo with the slum above the Canaanites' red brick city, if that. Truth be told, the Bible's great builder, the storied King Solomon, might have no earthly footprint inside the tel. That "would change the entire understanding of the history of Israel," Finkelstein wrote in *Levant*.

UNEARTHING THE LAYERS

Formulating a controversial hypothesis in a journal is one thing; proving it is something else. Yet that is the work of the tel, where the digging and sorting and quiet chatter form an oasis of calm amid war. A Palestinian boy has just been murdered by Israeli extremists, abducted outside his home and burned alive in retribution for the dead Israeli teens found in a ditch the week before. Now the Arab residents of Umm el Fahm, a hillside village near Tel Megiddo, are hurling rocks at cars.

Our buses take the long way, winding through back roads to the site in the early morning dark. At the tel, black protective tarps soar over a series of stepped-down grids, revealing the sandwich of cities, one by one.

It was 1998 when Eliezer Piasetzky, a nuclear physicist at Tel Aviv University, first visited these ruins. Although he professed just a passing interest in archaeology, Piasetzky was soon deeply enmeshed in the argument over the dates. Why not deploy radiocarbon dating, already used widely to date more ancient finds like dinosaur bones, he asked. The technique is based on the consistent ratio between two types of carbon molecules in all living things. When we die, one form, carbon-12, stays steady, but another form, carbon-14, slowly degrades at a known rate, allowing chemists to calculate how much time has passed since the sample died.

Finkelstein and Piasetzky refined the technique for their work at Megiddo, tapping the latest mass spectrometry equipment (to identify chemicals by their mass and charge), the top labs and samples likely to yield the most accurate results. They rejected wood samples that could be hundreds of years older than their use by humans, for instance, in favor of short-lived pits and seeds. An olive pit that happened to be cooking in a tabun (an ancient oven) at the moment of a violent destruction (such as an earthquake) was the best sample of all. Such a sample could not only be dated precisely, but could shed temporal light on everything crushed around it at the moment of the devastation.

With the new technique, the Megiddo researchers began to date buildings, pottery and olive pits to within a range of 40 years, a massive improvement over the 200-year increments archaeologists had dealt in before.

Finkelstein and Piasetzky now estimate that the red brick city of the Canaanites burned to the ground around 940 B.C. — about a decade before the end of Solomon's reign in 930 B.C. Since you need the passage of several decades, at least, between the destruction of one city and the erection of another, this would make it impossible for Solomon to be involved in the construction of the tel's monumental ashlar palaces — now dated by Finkelstein to the 800s (the ninth century B.C.) and linked to the reign of King Omri of the north.

Not everyone agrees. Using a competing radiocarbon dating technique, the meticulous, highly regarded Hebrew University archaeologist Amihai Mazar studied an equivalent burnt red brick city at

A cast of a seal inscribed with "Shema, Servant of Jeroboam" dates to around the eighth century B.C. Right: A palace first thought to date to Solomon and then dated to the ninth century B.C., under the Omride kings of the north, is at the heart of the debate over what falls under Solomonic rule.

A bottle found in a grave dates to the seventh century B.C.

a mound called Tel Rehov. Over the years, Mazar has moved the date of his red brick destruction from the conventional view of Yadin — right after the rise of King David — to as recently as 970 B.C.; his calculations leave Solomon's involvement in the construction of the ashlar palaces a possibility, but just by a hair.

In the end, the only way to learn the truth is still through better technology with resolution high enough to stamp a specific decade on a given neighborhood — like Finkelstein's Area K, a sloped grid of 5-meter squares notable for its four-room houses with central courtyards.

Through the centuries, as layer piled on layer, Area K residents served the city administrators: the bakers with their ovens, the metalworkers with their shops. As generations passed, new floors were built atop old, leaving household belongings buried in place. Scavenging K would be "like coming to someone's house and finding Coke cans on the floor," says Mario Martin, an archaeologist and expedition researcher directing this part of the dig.

The most revelatory part of K could be its human remains: skeletons of several individuals crushed under cedar beams in the Canaanite city of burnt red brick in the 10th century B.C.; and 22 people entombed under a single floor of a house dating to the Middle Bronze Age. Were the earlier Canaanites and the later Hebrews actually one and the same?

DNA should be able to provide some solid clues. To "track the movement and identity of residents through time and space," paleogeneticist Meirav Meiri dons her mask and gloves and descends through the layers, preparing samples for analysis at her Tel Aviv University lab.

Other researchers bring their labs right to the tel: Ruth Shahack-Gross from the University of Haifa runs an infrared spectroscopy unit at the edge of Area Q, another residential neighborhood, to learn what destroyed the red brick city and ended the Canaanite world. To do her work, she studies the chemical makeup of the destruction layers, which sometimes include bits and pieces of the tabuns. If the city was destroyed by earthquake, she can assume that conflagration started where fire was already burning — like the inside of an active tabun. If fire was brought by human invaders shooting flaming spears, areas of ignition would be random.

Using spectroscopy, Shahack-Gross can identify a variety of infrared signals coming from the clay, each indicative of a different molecular structure and pattern of ignition. Though she will need another excavation season to put the story together, she hopes to ultimately understand how fire moved through the tel and why the Canaanite world burned to the ground — by earthquake or invasion.

The tabuns could also resolve the dispute over Solomon's power and reach, says Amotz Agnon, a Hebrew University geophysicist reconstructing the history of Earth's magnetic field. Because the magnetic field influences the structure of rocks (and clay pots) during their formation, knowing the field's history allows you to tie specific objects to specific ranges of dates. The connection between the magnetic signature and the date can be more accurate than radiocarbon because local magnetic fields often spike, generating unique signatures that last as little as 10 years.

"If you find pottery inside the tabun that was fired right before a destruction, you could theoretically narrow your dates of an entire area to within a decade," he says. The work is still experimental, but if it eventually pans out, it could date the ashlar palaces with enough specificity to end the long-running dispute.

STORY THROUGH EVIDENCE

Memories accumulate and narratives coalesce over millennia. Those who wrote the Bible took characters from one

FROM LEFT: BIBLELANDPICTURES.COM/ALAMY; MEGIDDO EXPEDITION (4)

Above: Area K consists largely of domestic buildings. Each home's courtyard tended to be surrounded by four rooms for family living. Right: A team of researchers, including Ruth Shahack-Gross (in white), run infrared microscopy analysis along Area Q.

setting, scenes from another, political needs from a third, and they wrote a story, Finkelstein says. "The job of the archaeologist is to evaluate that story through evidence found in the Earth."

We are sitting in front of Megiddo's Assyrian palace. Only the foundation remains, but we can envision it all: Here an entry hall, there a courtyard and there a dining room. A hundred years after the Assyrians invaded Megiddo, the Deuteronomists were writing the Bible for the last great Davidic king, Josiah. But Josiah's world, too, crashed to a halt when the Egyptian pharaoh Neco killed him at — where else? — Megiddo. Some 25 years after Josiah's death, the Babylonians invaded Jerusalem, taking its lead citizens into captivity and destroying the temple built by Solomon — the first Temple of the Jews celebrated in the Old Testament and said to rest under the Temple Mount to this day.

Josiah's death, Finkelstein holds, explains why the concept of Armageddon, or an end times war between good and evil, centers here, at what the ancients called *Har Megiddô*. Some 700 years after Josiah's murder, John of Patmos — the likeliest author of the New Testament's book of Revelation — predicted an apocalyptic battle for Earth that will roil the ancient tel. "How did he think of that?" Finkelstein asks. "He was remembering all the past bloody battles and the death of Jesus' ancestor, Josiah." Megiddo made literary sense; as a metaphor, it gelled.

Many disagree. Back in Jerusalem, Eilat Mazar, an archaeology professor at Hebrew University long on the trail of the kings herself, says invoking mere metaphor sells the Bible short. Sitting in the office that once belonged to her grandfather, the pioneering biblical archaeologist Benjamin "Papa" Mazar, Eilat describes her approach: "If you pore over the Bible, you will find an astonishingly accurate historical core."

She found one clue in the passage where David views the biblical beauty, Bathsheba, bathing on her roof. "It could only happen if he was up high and she was down low," Mazar says. Surveying the possibilities, she quickly homed in on a rise leading to the Temple Mount. By 2005 she was reporting that "King David's palace," a stone building a quarter-acre large, attached to the Millo mentioned in the famous verse from 1 Kings. She dates the building to the 10th century B.C. because she has found 11th-century B.C. pottery beneath its floor. North of that, she believes she has found "Solomon's acropolis," a compound of three or four monumental structures she dates to his reign based on the red, burnished style of pottery atop its floor.

Finkelstein calls all this absurd. "The so-called palace could have been built any time after the 11th century B.C.," but before the time of the kings, he says, because "you date a building by pottery sitting on top of its floor, not beneath the foundation, on bare earth." And microarchaeology has already redated pottery of the style found at Mazar's acropolis to the ninth century B.C., a century after Solomon's death.

To which Mazar pulls out her grandfather's Bible and takes me back to 1 Kings 9. Right here it lists what Solomon built, she says. "The temple, the palace, the Millo, the wall around the city, and the huge construction enterprises in Hazor, in Megiddo and Gezer." The last three are tels. "It says Solomon built Megiddo. It says it right there."

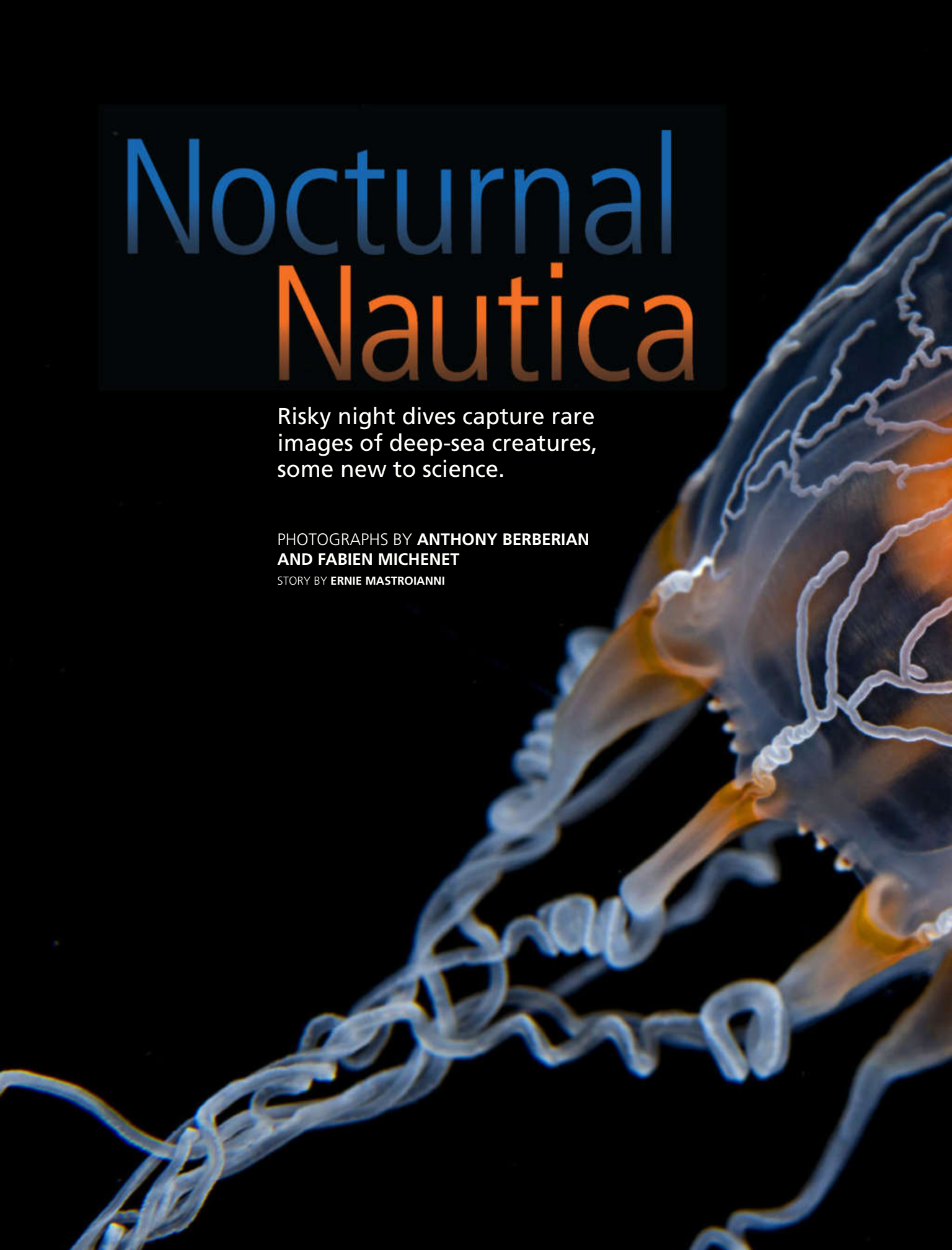
Whatever the truth, Megiddo was once truly alive. "These were all real cities," says Eric Cline, an archaeologist and historian at George Washington University who is a former co-director of the Megiddo dig. "Depending on the era, between 1,000 and 10,000 people lived here. Each one had a cup of wine for dinner. People were living and dying and crying. They were heartbroken, they were in love." D

Pamela Weintraub *is a contributing editor for* Discover.

Nocturnal Nautica

Risky night dives capture rare images of deep-sea creatures, some new to science.

PHOTOGRAPHS BY **ANTHONY BERBERIAN AND FABIEN MICHENET**
STORY BY **ERNIE MASTROIANNI**



Eutiara

"This wonderful creature is a completely new species," says Anthony Berberian. It seems to be a jellyfish from the *Eutiara* genus, family Pandeidae. The umbrella is less than an inch long, but the tentacles are about 3 feet. Like similar tentacled invertebrates, it is likely venomous. Jellyfish specialist Jacqueline Goy is working on a paper with the pair to describe and name it.

For the past few years, a pair of French Polynesian photographers have been taking outsize risks to study the smallest of creatures off the Tahiti coast. Fabien Michenet and Anthony Berberian are physicians by day, but at night they dive between 66 and 164 feet underwater to document an astonishing diversity of plankton species. These tiny, free-drifting creatures are rarely seen in the wild, a few are new to science, and all appear alien. Plankton provide the basis for nearly all the ocean's food chain and energy production.

Three groups account for most plankton species: Microscopic phytoplankton produce nearly half of all the world's oxygen through photosynthesis; bacterioplankton decompose material and recycle chemicals; and zooplankton are the animals that feed on phytoplankton and draw most of the photographers' attention.

With an array of sophisticated digital cameras, macro lenses and underwater strobe lights, Michenet and Berberian make their night dives from an inflatable boat only 16 feet long, positioned about 1 to 3 miles off the Tahiti coast, where the Pacific Ocean bottoms out about 7,000 feet below.

"We attach a small light under the boat that guides us, and then we dive under the boat, which is left alone to drift with the wind and the current. Nobody stays on board when we dive," says Berberian. Apart from

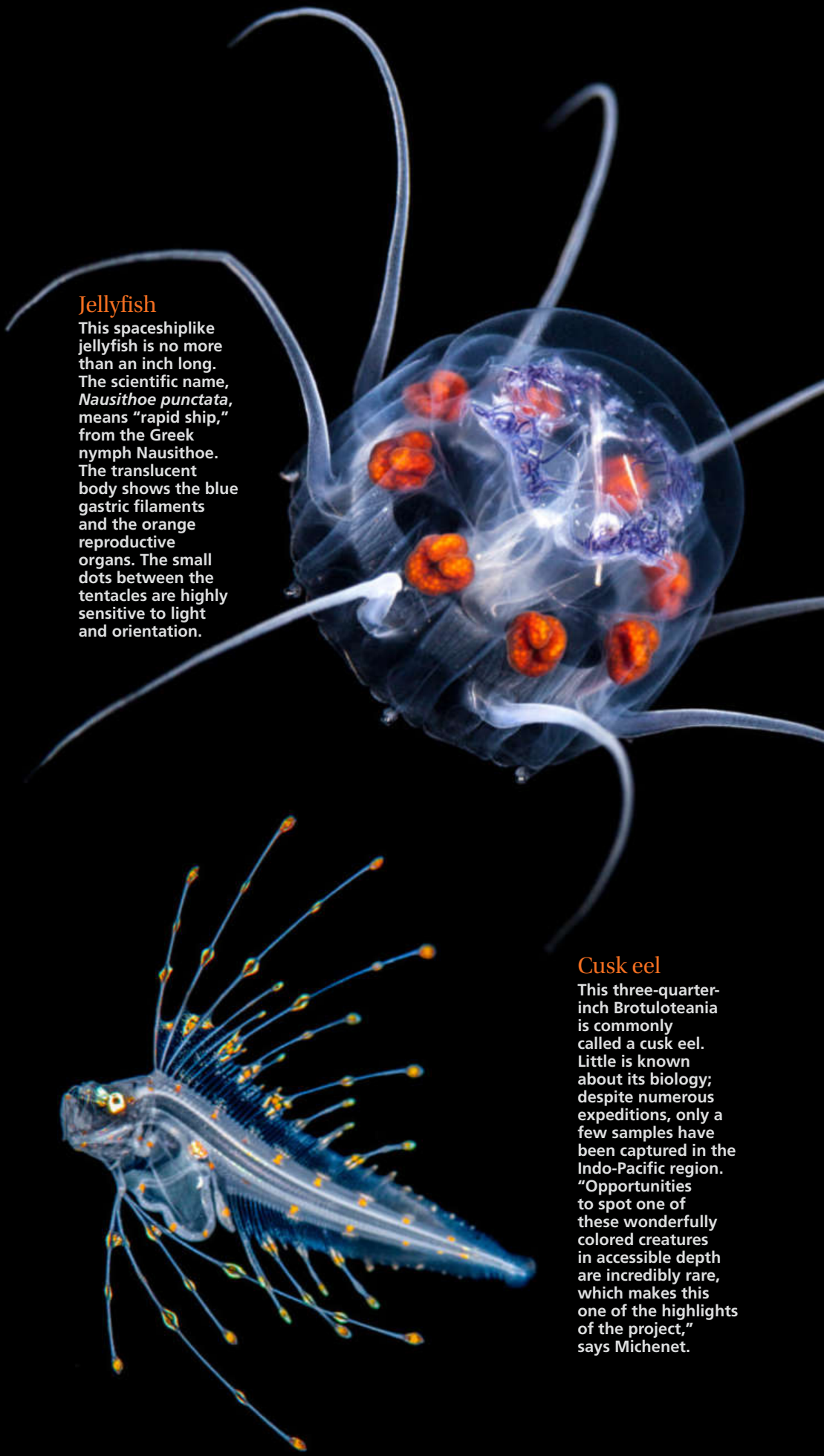
an occasional hammerhead shark or aggressive dolphin, they're alone but perfectly positioned to photograph the plankton that rise from deeper water to feed under the cover of darkness.

This movement of ocean sea life is part of a diurnal worldwide cycle called diel vertical migration. Researchers want to know more about this process and value the photos Michenet and Berberian take during their nocturnal excursions.

Dave Johnson, a biologist who specializes in fish with the Smithsonian National Museum of Natural History, has worked with the pair and says such images offer scientists a "unique perspective on this oceanic microcosm." Berberian is working with French jellyfish expert Jacqueline Goy to jointly publish a paper about a new species from the genus *Eutiara* (see opening page) discovered from the men's photos.

What this intrepid duo seeks simply cannot be photographed in daylight or easily in a lab. "We've tried to do the same kind of dive by day," says Michenet, "but there was nothing to be seen for miles around. It seems these creatures hide deeper by day." And documenting these plankton in the wild gives researchers a glimpse at the delicate creatures intact. They're often damaged when collected for observation in a lab. The night dives "allow us to document behaviors, associations, predation and parasitism in a natural way," says Michenet. D

***Ernie Mastroianni** is the photo editor of* Discover.



Jellyfish

This spaceshiplike jellyfish is no more than an inch long. The scientific name, *Nausithoe punctata*, means "rapid ship," from the Greek nymph Nausithoe. The translucent body shows the blue gastric filaments and the orange reproductive organs. The small dots between the tentacles are highly sensitive to light and orientation.

Cusk eel

This three-quarter-inch Brotuloteania is commonly called a cusk eel. Little is known about its biology; despite numerous expeditions, only a few samples have been captured in the Indo-Pacific region. "Opportunities to spot one of these wonderfully colored creatures in accessible depth are incredibly rare, which makes this one of the highlights of the project," says Michenet.

Phronima in a salp

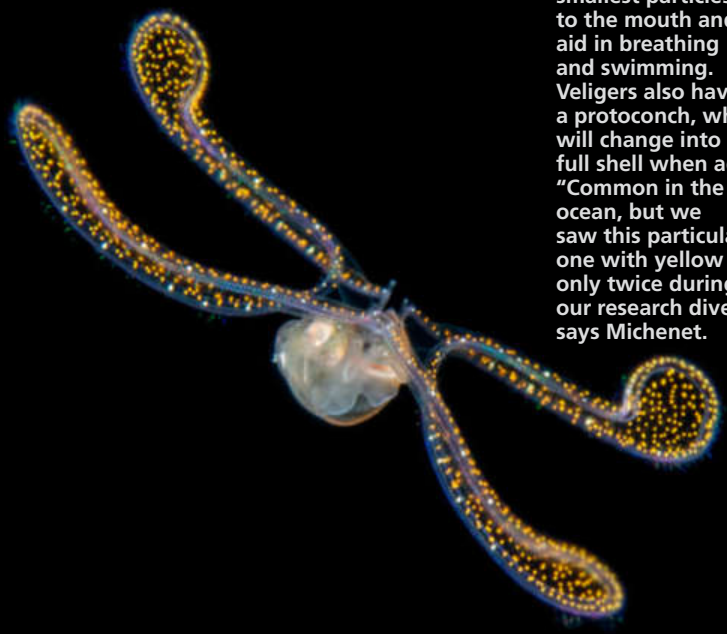
Phronimas are less than 2 inches long. They feed on gelatinous salpa, then use the remaining shell as a shelter. When they breed, the small babies eat the rest of the host, then swim away to find new prey. They are among the few crustaceans that raise their offspring. They have four eyes, two of which look upward to catch the remaining light of the surface — hence the elongated, monstrous-looking head.

Scalloped ribbonfish

This juvenile scalloped ribbonfish, less than 2 inches long, will grow to more than 4 as an adult. It is closely related to the longest bony fish in the world, Regalec (*Regalecus glesne*), which can grow to more than 50 feet. Fishermen and scientists have seen these ribbonfish alive only a few times.

Veliger

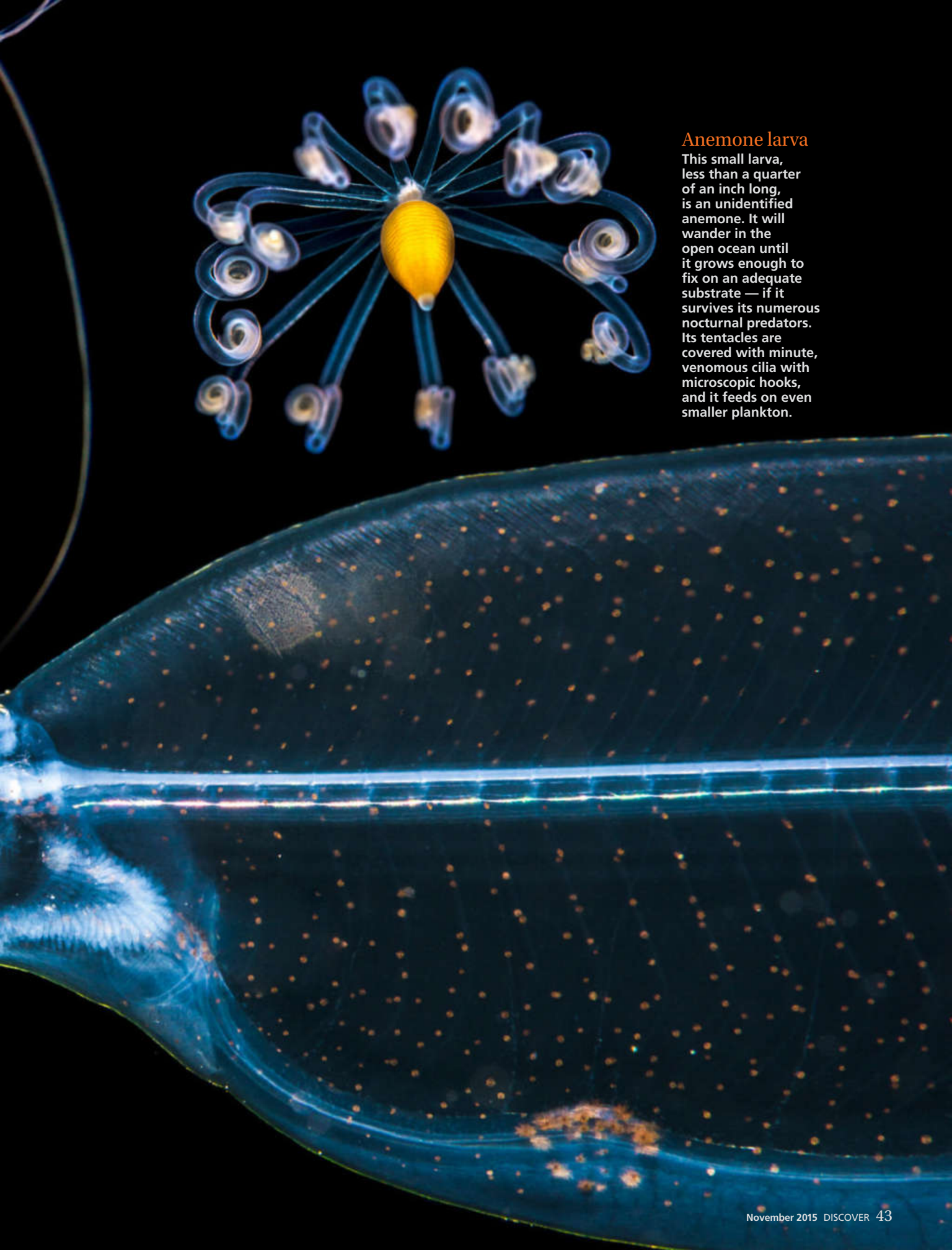
This colorful veliger, measuring less than an eighth of an inch, is a planktonic larva of an unidentified sea snail. The arms, called velum, are made of synced cilia that vibrate to move the smallest particles to the mouth and aid in breathing and swimming. Veligers also have a protoconch, which will change into a full shell when adult. "Common in the open ocean, but we saw this particular one with yellow dots only twice during our research dives," says Michenet.



Leptocephalus

(family Ophichthidae)

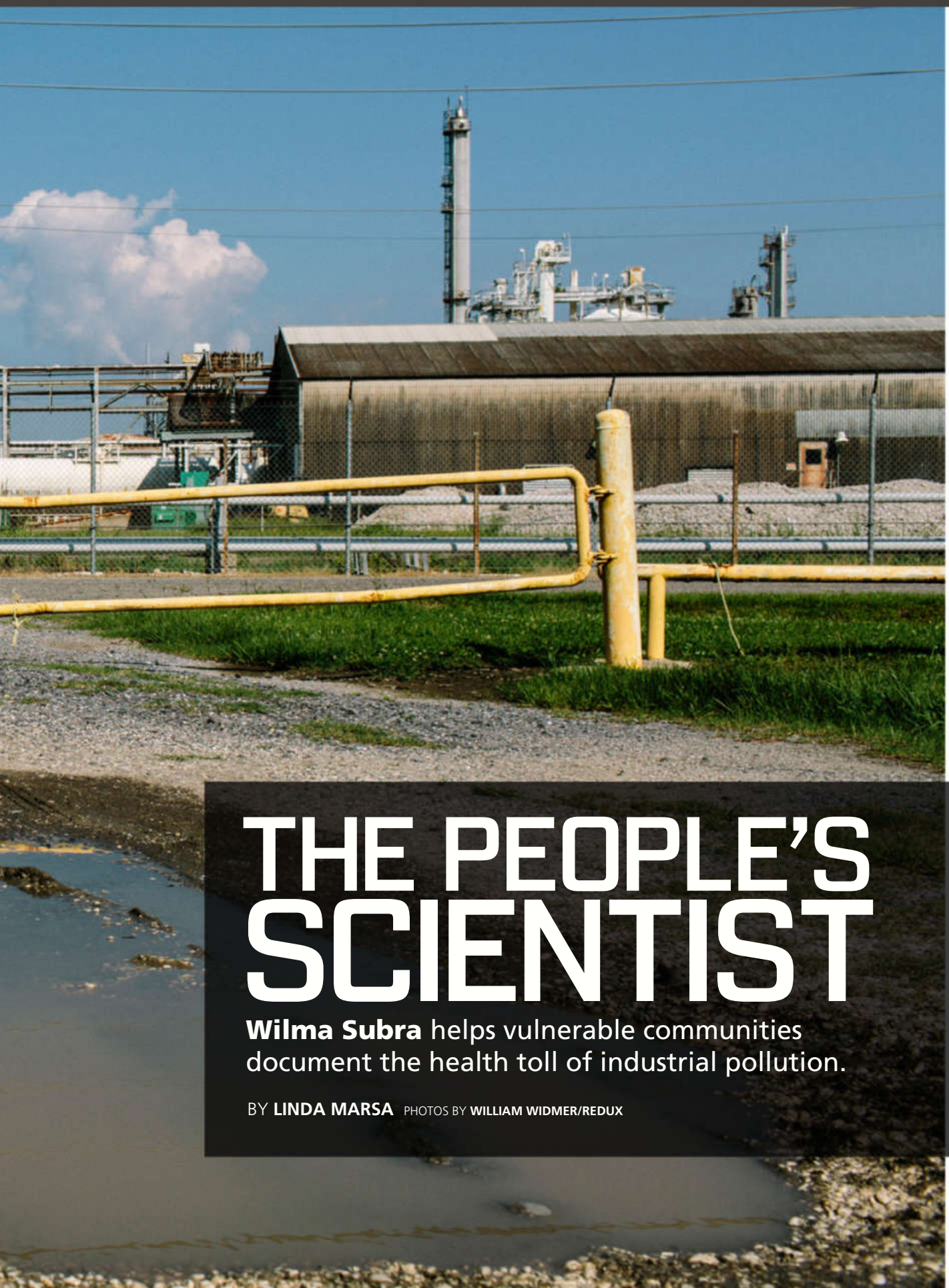
This leptocephalus is a larva of an unidentified snake eel. Measuring 4 to 5 inches, it is entirely transparent and shaped like a wheel when stationary. In motion, it behaves like a snake and can quickly vanish in the darkness of the deep.



Anemone larva

This small larva, less than a quarter of an inch long, is an unidentified anemone. It will wander in the open ocean until it grows enough to fix on an adequate substrate — if it survives its numerous nocturnal predators. Its tentacles are covered with minute, venomous cilia with microscopic hooks, and it feeds on even smaller plankton.

Wilma Subra collects air quality data at a park in the Diamond district of Norco, La., bordered by a Hexion chemical plant.



THE PEOPLE'S SCIENTIST

Wilma Subra helps vulnerable communities document the health toll of industrial pollution.

BY **LINDA MARSA** PHOTOS BY **WILLIAM WIDMER/REDUX**

The contrast couldn't be more stark: Only a chain-link fence, camouflaged by thick bushes and mighty oak trees, separates residents from a Shell chemical plant and the Motiva oil refinery. On one side is a verdant park, with a gazebo and a children's slide, surrounded by a handful of small, tidy clapboard homes with well-tended lawns. On the other side is a huge industrial zone: low-slung concrete and corrugated buildings, and vast storage tanks connected by a maze of thick pipes. Smokestacks spew clouds of noxious chemicals.

This is the Diamond district of Norco, a Mississippi Delta hamlet about 25 miles west of New Orleans. It's like a ghost town now — empty and quiet, even at midday. Tall grasses have overtaken open fields where homes once stood. This used to be a thriving African-American neighborhood of 1,500 with roots that go back more than 200 years. Today, it's home only to a couple of dozen families.

Ever since Shell built the plant in the 1950s, locals who lived near the fence line complained of the acrid rotten-egg smell that permeated the neighborhood, and of the toll they believed toxic exposures took on their health — alarmingly high rates of asthma, uncommon cancers, rare autoimmune disorders and respiratory illnesses. There were frequent accidents and two fatal explosions, including one in 1988 that killed seven workers, injured 48 others and forced more than 4,000 area residents to evacuate.

Yet since the mid-1970s, Shell Oil had rebuffed residents' demands to be relocated from the contaminated properties, and they even lost a 1997 lawsuit because they couldn't convince a jury that plant emissions posed a health risk.

Then Wilma Subra stepped in — with a plastic paint bucket outfitted with a simple battery-operated pump to collect air samples — and provided residents with the clear evidence they needed.

Subra, a chemist and microbiologist who works gratis with poor communities to take on big corporations, held workshops at a local church to teach residents how to use the buckets to collect air samples and keep diaries so they could match their physical symptoms with what they smelled in the air. Then they'd compare those logs with the emissions that the company is required to report to state and federal agencies.

While this type of sampling is rudimentary, the bucket tests were more than what Louisiana's Department of Environmental Quality had done; the regulatory agency relied mainly on Shell's emissions data, which indicated that concentration levels of pollutants fell below the permitted state limits.

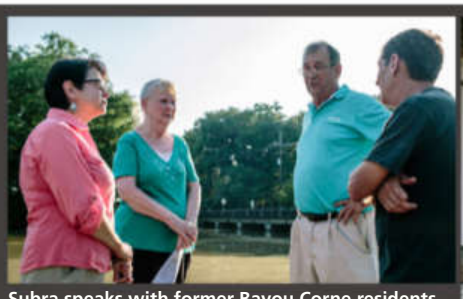
Subra's analysis allowed community members to correlate their symptoms with the company's reported emissions. They found they were being exposed to 100 to 1,000 times higher concentrations of benzene, toluene, methyl ethyl ketone and other toxic substances than people living in other areas of rural Louisiana. What's more, their investigation detected releases that the plant hadn't reported to state regulators.

"Wilma turned the tide just when we all felt like giving up," says Margie

MAP: ALISON MACKEY/DISCOVER

Richard, a retired schoolteacher who headed the Concerned Citizens of Norco, a grass-roots group that battled Shell Oil. Armed with these findings, Richard and her fellow activists presented their results to anyone who would listen, including the U.N. Commission on Human Rights, where Richard gave a well-publicized speech in Geneva in 1999. Soon, environmental groups, the EPA and the media took notice. A chastened Shell worked with the activists to set up monitoring stations throughout the neighborhood. Soon after, the company paid $30 million to buy and raze 250 houses in the Diamond district and relocate many residents.

"They just wanted us to go away, but Wilma gave us the proof we needed to get justice," says Richard, who now lives in nearby Destrehan.



Subra speaks with former Bayou Corne residents (from left) Mona Dugas, Mike Schaff and Randy Rousseau. Rousseau and Schaff were forced to evacuate their homes after a chemical company's salt mine collapsed in 2012 and led to a giant sinkhole on the outskirts of Bayou Corne, about 80 miles west of New Orleans.

A TOP GUN IN BATTLE

Rural hamlets like Norco are familiar turf for Subra, who was born in 1943 and raised in Morgan City, about 70 miles southwest of Norco, near the marshy bayous and swamplands of Louisiana's Gulf Coast. She now lives nearby, in New Iberia, a city of about 30,000 on the banks of Bayou Teche, flanked by restored antebellum mansions and the tree-lined streets of a historic downtown. With her sweater sets, sensible shoes and blond hair pulled back in a tight bun, the soft-spoken grandmother looks more like a favorite high school teacher than a tree hugger.

A chemist by training and an environmental activist by avocation, Subra is a true original: "the people's scientist," says Michele Roberts, a scientist who is a national co-coordinator at the Environmental Justice and Health Alliance for Chemical Policy Reform in Washington, D.C.

Subra's work in refinery communities like Norco exposes the racial and economic fault lines in rural America, where impoverished communities of color often become the dumping ground for our nation's toxic wastes. In the past three decades, Subra has been involved in more than 800 grass-roots struggles across the nation, from groundwater contamination stemming from natural gas extraction in Texas, Wyoming and North Dakota to pollution from shipyards in the San Francisco Bay. Her free technical assistance has helped level the playing field for hundreds of poor towns battling corporate giants. Because of Subra's efforts, thousands of residents — beset with health problems that stem from the collateral damage of industrialization, including groundwater contamination, pesticide misuse, oil field waste, toxic landfills and hazardous waste incinerators — have been armed with the tools to get a fair shake.

"She is the voice of greatness," says Russel Honoré, the now-retired U.S. Army lieutenant general who became a local folk hero when he led search and rescue and evacuation after Hurricane Katrina and later founded the GreenARMY, a coalition of environmental groups fighting against pollution in the Gulf region. "She has the profound ability to communicate in language people can understand about the impacts of hazardous materials and the consequences of the actions of the petrochemical industry."

> "They just wanted us to go away, but Wilma gave us the proof we needed to get justice."

Subra's missionary zeal hasn't diminished over the years. At an age when most people are thinking about retirement, the 72-year-old scientist is involved in some of her biggest struggles yet, including getting justice for victims of the 2010 BP oil rig explosion and spill and blocking the construction of a plant in the town of Mossville in western Louisiana. "I was up at 3 a.m. reading my email, and I thought, 'I shouldn't be doing this,'" Subra tells me on a sweltering September day over lunch at a downtown New Orleans hotel. "But these issues just keep going. And if you let frustration get in the way of being able to get something done, then somebody's not going to get what they need from you."

But much of her work has centered on an 85-mile corridor along the Mississippi River from Baton Rouge to New Orleans, where chemical plants and refineries pump out millions of pounds of toxic substances each year. Louisiana is ground zero for toxic dumping, she believes, because of lax enforcement in a state dominated by the petrochemical industry. "Because

A large petrochemical complex lines the western bank of the Mississippi River, across from the small town of Norco, La.

we're so energy-intense, everything goes here," Subra says. For example, a 2014 audit by the Louisiana Legislative Auditor found that the state's cash-strapped Office of Conservation, which regulates the oil and gas industry, had failed to plug nearly 3,000 orphaned wells and hadn't fined companies with well-inspection violations. The audit also found that the agency had failed to inspect more than half of Louisiana's 50,000 oil and gas wells every three years as required by law.

Yet even industry executives consider her a worthy adversary. "She's always been highly respected, courteous and professional," says Dan Borné, president of the Louisiana Chemical Association, an industry trade group. He describes Subra as one of the environmental movement's "top guns."

Subra has earned many accolades: a MacArthur "genius grant" and the Global Exchange Human Rights Award, among numerous others. She's testified before Congress, lectured at Harvard, helped draft environmental laws and served on numerous governmental panels. "She is respected among scientists and companies across the board, which is a reflection of the methodical and thoughtful work that she does," says David Gray, director of the office of external affairs for the EPA's Region 6, based in Dallas. "Even when we disagree, she brings a healthy dialogue to the table about pretty complex issues."

UNLIKELY CRUSADER

The Louisiana native didn't start out as an environmental crusader. The daughter of an inventor, she learned technical skills — like doing chemical analysis — from the time she was in middle school, pitching in during the summer at her father's company, which ground up oyster shells for use in paints, cosmetics and pharmaceuticals.

The valedictorian of her high school class, Subra got her master's degree in microbiology, chemistry and computer sciences from the University of Southwestern Louisiana in Lafayette. In 1967, she started work at the Gulf South Research Institute, a state-funded agency that did toxicology studies. Although the institute conducted mostly animal studies, dosing lab rats and mice with different agents that potentially cause cancer, researchers also tested blood and urine from people who were exposed to chemicals in the area. During her 14 years there, Subra grew frustrated that she couldn't share her findings with residents because of the company's confidentiality agreement. Test results were turned over to federal agencies like the EPA or the Centers for Disease Control and Prevention, which strictly regulated their distribution.

The turning point came in 1980, when her lab tested workers at the Blue Grass Army Depot near Lexington, Ky., where crates of ammo from Vietnam had been stored to be decommissioned. The employees, who were civilians from poor parts of Appalachia, took the wood crating home and used it to panel walls, build bookcases or burn in the fireplace.

"The wood had been soaked in so

much pentachlorophenol that it was dripping out of the train cars," says Subra, who adds that the EPA recently categorized the pesticide as a likely carcinogen. "We found it in the blood and urine of the workers, and it had also contaminated the air and the soil when they took it home. But we were never able to go back to the community and tell them what we had found. And these people had a right to know."

In 1981, she founded the Subra Company, a consulting firm that conducts chemical analyses for food companies and provides free technical assistance to community groups. She spends most of her time giving advice to residents dealing with oil, chemical and hazardous waste spills and pollution, using her expertise to expose malfeasance by entrenched corporate interests without a second thought to her own personal safety. She's been threatened, harassed, had her office burglarized and computers stolen — forcing her to move her office from a trailer near the four-lane blacktop highway that cuts through south Louisiana to a cozy file-filled cottage on her property across from sugar cane fields. She's even been shot at — authorities never learned who fired the gun while Subra was working at a desk by her front window — but she takes it all in with remarkable equanimity.

In one of her earliest cases, in the early 1980s in Vermilion Parish, she got a call from a man whose wife and father were both dying of cancer. Since the area has about 55 waste sites, she analyzed the tap water from different private wells and discovered the presence of four heavy metals linked to oil field waste. After she revealed her findings to residents, the Louisiana health department warned her to stop telling people not to drink the water. The state was stuck. It knew there was a problem but didn't have the dollars for cleanup — until its own investigation uncovered so much toxic waste in the groundwater that the EPA stepped in and declared three of the dozens of dumps as Superfund cleanup sites. This

Industrial Battlegrounds

Over 30 years, Wilma Subra's reach has extended to more than 800 communities. Here are a few examples of issues she's helped residents tackle:

Shale Oil Development

- **Marcellus and Utica Shale** – Pennsylvania, New York, West Virginia, Maryland, Ohio
- **Bakken Shale** – North Dakota, Montana
- **Fayetteville Shale** – Arkansas
- **Tuscaloosa Shale** –Louisiana, Mississippi
- **Permian Basin** –Texas, New Mexico
- **Woodford Shale** – Oklahoma

Coal Bed Methane

- Powder River basin of Wyoming
- San Juan basin of New Mexico
- Colorado, Alaska, Alabama

Toxic Landfills

Utah, Illinois, Mississippi, Louisiana

Polluted Shipyards

San Francisco, Alabama, Louisiana

Industrial Toxic Air Emissions

- Louisville, Ky.
- New Jersey industrial corridor
- Humphreys County (Tenn.)
- Mississippi, Texas, Alabama, Florida, California

Pesticide Misuse

- California
- Southern half of Louisiana

Injection Wells

Louisiana, Texas, Mississippi, Alabama

Vinyl Chloride Facilities

Across the United States, as well as Japan and Israel

BP Oil Spill Impacts

Louisiana, Mississippi, Alabama, Florida, Texas

designation freed up federal money to deal with the contaminants. "We managed to keep a new waste site out," Subra recalls. "Finally the industry people said, 'OK, Wilma, enough, we'll work with you to get some of them cleaned up voluntarily.'"

The Vermilion Parish experience set the pattern for the rest of her career: concerned residents with health problems, coupled with resistance from companies and local authorities. By the time the Deepwater Horizon oil rig exploded and caught fire late in the evening on April 20, 2010 — killing 11 workers and injuring 17 others — it seemed like half of south Louisiana had her on speed dial. In the early morning hours after the blast, she fielded frantic

Fire boats battle a blaze after the explosion on the Deepwater Horizon oil rig in April 2010.

U.S. COAST GUARD

"They'd be very sick, but they needed the job, so they'd go out the next morning. I was educating people all along the coast … talking about the chemicals they were being exposed to and how they needed protective gear."

phone calls from all over the coast. "All the families around here had no idea whether their loved ones were dead or alive or injured," she recalls. "They were just desperate."

The paperwork related to the explosion nearly fills an entire room in Subra's cluttered offices. In what is perhaps the worst man-made environmental disaster in American history, the BP spill ultimately spewed 4.2 million barrels of oil into the Gulf before the well was sealed. In addition, officials used 1.8 million gallons of the chemical dispersant Corexit to break up the oil. Subra, along with other scientists, believe that mixing such large quantities of dispersants with the millions of barrels of sweet crude unleashed a toxic brew that has sickened thousands of locals, including some of the 170,000 people who worked in some capacity on BP's cleanup operation.

Crude oil itself contains heavy metals, benzene, hexane, toluene and PAHs (polycyclic aromatic hydrocarbons) that can damage DNA, leading to leukemia and lymphomas, and destruction of parts of the brain that regulate memory and motor skills. Corexit and oil together are synergistic, according to Subra and other scientists. The dispersant acts like an oil delivery system, breaking down the crude so the toxic substances can seep through skin.

High winds hitting the 68,000-square-mile slick carried the mixture of crude and Corexit up to a hundred miles inland. Many fishermen and the frontline cleanup workers, including the boat captains and deckhands out in the Gulf, believe they were sickened by the aerial spraying of dispersants. At night they'd call Subra, who estimates she got 300 to 400 calls with the same complaints: dizziness, stinging eyes, severe headaches, nausea, respiratory ills. "They'd be very sick, but they needed the job, so they'd go out the next morning," she says. "I was educating people all along the coast … talking about the chemicals they were being exposed to and how they needed protective gear."

But EPA officials kept reassuring Subra that the dispersants weren't sprayed during the day. Subra buttonholed Obama administration officials visiting the Gulf, including EPA director Lisa Jackson. She testified before Congress and teamed up with Marylee Orr, executive director of the Louisiana Environmental Action Network (LEAN), to order protective gear and respirators. The workers had the gear by early May but were told they would be fired if they wore them because it wouldn't look good for the TV cameras; BP denies ever doing this. "Over the long haul," says Subra, "we were never successful in getting the workers to be able to wear the gear."

In the five years since the spill, Subra believes not nearly enough has been done to address the health consequences faced by the cleanup workers, their families and thousands of Gulf Coast residents. Many report remarkably similar symptoms, such as nausea, difficulty breathing, memory lapses, liver damage, seizures, hypertension, blood in the urine and rectal bleeding, and some suffer from profound depression and anxiety. BP agreed to a settlement

After the BP spill, workers clean up the beach along Gulf Shores in southern Alabama in June 2010. Subra has pushed to address the health consequences still faced by thousands of cleanup workers in the five years since the oil rig explosion.

XINHUA NEWS AGENCY/EYEVINE/REDUX

in 2012 that will compensate victims up to $60,700 per person (separate from the $18.7 billion environmental fine the oil giant agreed to pay in July 2015). But Subra doesn't think this is adequate for people whose lives have been permanently derailed.

"We have tons of workers who have lost their house, have lost their vehicles, with no way of supporting their family and are too sick to go to any kind of job," says Subra. "This includes women, too, who were hired to cook for the workers on the boats, and who washed the clothes that were just dripping with chemicals. They're being ignored."

FIGHTING FOR DECADES

Subra knows how the fights can go on for decades. Take Mossville, a predominately African-American community in western Louisiana that has the state's densest concentration of industrial facilities. There are 14 industrial companies in the area, and many manufacture vinyl chloride, which produces dioxins, a group of chemicals that accumulate in the food chain and are classified as carcinogens. The federal Agency for Toxic Substances and Disease Registry conducted blood tests in 2006 that revealed residents' blood dioxin levels were three times the national average. But it wasn't until Subra compared the raw data from the study with the EPA's inventory of dioxin emissions from Mossville facilities that residents could show a direct correlation between the dioxins in their blood and those emitted by the plants. Still, nothing happened.

By 2012, the community faced yet another industrial site. The South African chemical and oil giant Sasol wanted a permit to build the first U.S. facility that converts natural gas into diesel fuel — the largest industrial project in the state's history. In a series of hearings, Subra presented her findings on the area's pollution levels, and she was accompanied by a parade of ill residents. But the state environmental quality agency approved the request.

After meetings with activists, Sasol offered home buyouts (more than 80 percent of locals have signed up) and scholarships for training programs that target underemployed residents. The company is also working with the Imperial Calcasieu Museum to collect oral histories of the region. "We're trying to be responsive to the needs of the community," says Michael Hayes, Sasol's manager of public affairs. But Subra believes it will essentially spell the end of this centuries-old town. "They just received their wetlands permits, so it's a go," she says sourly. "But Mossville is dying because they've ripped the social fabric apart."

Yet she remains undaunted. There is always another case, and another phone call from someone who needs her help. "There's just so much to do," says Subra. "If we're not there as a pushback, then they're going to just run over us and destroy the environment and all human health in the name of economic development." D

Linda Marsa *is a contributing editor for* Discover *and author of* Fevered: How a Hotter Planet Will Hurt Our Health and How We Can Save Ourselves *(Rodale).*

ROOTED IN TRUTH

Modern science could explain mythic tales of transformation.

BY **MATT KAPLAN**

FOR MILLENNIA, MYTHOLOGY HAS SERVED as a vessel for passing down traditions and knowledge in countless cultures. Sometimes, though, these tales seem a little too tall, especially those of magic that transforms men into beasts. But if you examine them closely, there are some slivers of truth, and they might actually be based in science.

Among the most famous of these myths is part of Homer's *The Odyssey*. During their wanderings, Odysseus and his crew arrive at the island of Aeaea. Starving and exhausted, they split into two groups to search for resources, and one group stumbles upon a palatial home. A beautiful woman emerges and welcomes the men inside for a feast. All but one of them follow her.

This is no ordinary woman. This is the sorceress Circe — fabled daughter of the goddess of magic, Hecate — and as she prepared the feast for the men, the story says she:

> *… made for them a potion of cheese and barley meal and yellow honey with Pramnian wine; but in the food she mixed baneful drugs, that they might utterly forget their native land. Now when she had given them the potion, and they had drunk it off, then she presently smote them with her wand and penned them in the sties.*

Terrified by what he sees, the one crew member who did not enter Circe's home races into the wilderness to tell Odysseus of the horrible incident that transformed the men into pigs. Determined to rescue his men from this witchcraft, Odysseus travels through a forest to Circe's home. Along the way,

THE SORCERESS CIRCE dosed Odysseus' men with a drug derived from a plant that likely exists in the real world, and not just in the classical legend.

MASTERPICS/ALAMY

he encounters a young man who reveals himself to be Hermes, a god most often thought of as a messenger deity but who was also associated with healing. Hermes, aware of potential danger, digs up a plant in a nearby meadow and hands it to the hero, saying:

> *Here, take this potent herb, and go to the house of Circe, and it shall ward off from thy head the evil day. And I will tell thee all the baneful wiles of Circe. She will mix thee a potion, and cast drugs into the food; but even so she shall not be able to bewitch thee, for the potent herb that I shall give thee will not suffer it.*

That Circe's power seems to stem from a knowledge of poisons suggests something real might be behind the tale.

What is most intriguing about the text is that it is specific about where Hermes' medicine comes from and what it looks like. Odysseus says:

> *So saying, [Hermes] gave me the herb, drawing it from the ground, and showed me its nature. At the root it was black, but its flower was like milk. Moly the gods call it, and it is hard for mortal men to dig; but with the gods all things are possible.*

True to the god's word, the moly renders Odysseus invulnerable to Circe's magic. He drinks her potion, eats her food and stands there as she points her wand at him. However, when she tells him to join his friends in the pigsty, he resists the spell and rushes her with his sword.

Without the mention of drugs being mixed into the food, it would be easy to shrug off such a myth as the stuff of pure imagination. However, that Circe's power seems to stem from a knowledge of poisons suggests something real might be behind the tale.

One of the most common arguments is that Circe was feeding the crew jimson weed. While that sounds innocent enough, *Datura stramonium,* as it is known in the scientific world, belongs to the deadly nightshade family and contains high levels of anti-cholinergic alkaloids such as scopolamine, hyoscyamine and atropine. These compounds block the neurotransmitter acetylcholine from interacting with its receptors in the brain. When this neurotransmitter is blocked, we can't distinguish reality from fantasy, we exhibit bizarre behavior, and we can suffer pronounced amnesia. "Patients who consume this stuff often have vivid hallucinations and become seriously delirious," says Harvard Medical School toxicologist Alan Woolf.

One academic analysis of the anti-cholinergic alkaloid cocktail sums things up rather nicely: "No other substance has received as many 'train wreck' negative reports [with] the overwhelming majority finding their experiences extremely mentally and physically unpleasant and not infrequently physically dangerous."

Circe was likely using *Datura* and not some other poison for two reasons. First, jimson weed is found all over the classical world. Second, *The Odyssey* makes it clear that Circe expects the crew to forget their fatherland. More specifically, she is expecting an amnesia-like effect on par with what *Datura* actually causes.

As for her use of the wand, the earliest pottery depicting Circe does not show her pointing the wand at the men but rather mixing poison into food with it. Given this art, a case can be made that the wand in the original story was not a wand at all but an ordinary stirrer that ultimately came to be drawn as a magical object rather than an everyday kitchen utensil. Or perhaps the wand was just a theatrical prop to punctuate Circe's power.

It's fascinating that, over the centuries, this role of the wand in magic has not changed much. In one of the core texts that many modern stage magicians read while in training, Professor Hoffmann's *Modern Magic*, the wand is described as an ideal prop for distracting the eyes, for granting an excuse to close the hand and hide

AFTER THE MEN DRANK CIRCE'S potion, they morphed into pigs (above). The plant Circe used could have been *Datura stramonium*, or jimson weed (right). Part of the nightshade family, this plant can cause amnesia, hallucinations and delirium when consumed.

Subscribers can read an extended version of this story at www.DiscoverMagazine.com/Mythology

TOP: CHRONICLE/ALAMY. BOTTOM: WELLCOME LIBRARY, LONDON

something within it, and to provide the illusion of having real magical power.

Yet *Datura* is not the only real-world element found in *The Odyssey*. In 1951, during the Cold War, pharmacologist Mikhail Mashkovsky at the Russian Academy of Science discovered that villagers in the Ural Mountains used what could be the protective plant Hermes gave Odysseus. The villagers were rubbing ground-up snowdrop flowers into their skin as a pain reliever and using the snowdrop plant as a medicine to help children afflicted with polio to fight off the paralysis that was so often caused by the dreaded disease.

Fascinated by this, Mashkovsky and colleague Rita Kruglikova-Lvova explored the effects of a compound extracted from snowdrops on the muscles of frogs, rabbits and guinea pigs, and the brains of rats. This experimentation led the researchers to conclude in the late 1950s that the compound could protect specific neurotransmitters from being damaged by diseases and toxins.

The snowdrop compound galantamine was soon registered as Nivalin in Bulgaria in 1959, and from there it began its slow journey into the West. Today, the drug is proving more valuable than ever in the battle against Alzheimer's disease.

First described in 1907 by the German psychiatrist Alois Alzheimer, the disease is vicious and progressively destroys memory and cognitive function. In the late 1970s, a team of researchers found that people who died of Alzheimer's commonly had brains deficient in acetylcholine, the same neurotransmitter that *Datura* blocks.

This discovery paired well with reports that the most common brain deficit found in Alzheimer's patients was cholinergic in nature and led several research groups to argue that the disease arose from an inability to transmit signals across cholinergic synapses. Galantamine's ability to protect acetylcholine seemed perfect for staving off the effects of Alzheimer's, and it is now widely used for this purpose.

Could this be Homer's moly? In 1981, as the drug's origins started to become better known, neurologists Andreas Plaitakis at the Mount Sinai School of Medicine in New York and Roger Duvoisin at Rutgers Medical School in New Jersey proposed at the Twelfth World Congress of Neurology that snowdrop might have been the plant that Hermes handed to Odysseus.

To support their argument, they pointed out that the plant was commonly found in Greece, that it grows in forest glens like the one visited by Hermes, and that it is an effective antidote to *Datura*. They also noted that its petals were milky white and that it had a darkly pigmented root just as the moly described in *The Odyssey.* Moreover, galantamine is not like many other anti-cholinesterases that break apart and become useless in the body rather quickly. Galantamine endures, producing a lasting protection that prevents acetylcholine from being blocked, which would have made it perfect for the situation Odysseus found himself in.

Did the Greeks really know that snowdrop could stave off neurotransmitter-attacking poisons and diseases? I suspect they did. There isn't a lot of direct evidence, but Theophrastus, a Greek writer from the fourth century B.C., writes in his text *Historia plantarum* that moly "is used as an antidote against poisons." This knowledge must have been woven into stories long ago and transformed from history into legend and from legend into myth in most parts of the world. What is wonderful is that the myth lives on.

For example, it makes a cameo in the 2007 film *Stardust*. The evil witch in the tale tries, and fails, to harm the hero, Tristan, with her dark magic. The reason for her failure? He was wearing a milky-white flower on his coat. The species looked familiar, so I pulled up the script, and sure enough, there was its name:

> *Girl: You shouldn't buy the bluebells. Buy this one instead. Snowdrop. It'll bring you luck.*

If snowdrop was Homer's moly, over the ages it was almost forgotten. For the sake of those suffering from Alzheimer's, I'm glad Mashkovsky found its powers before they were completely lost to the ravages of time.

Does this mean that Odysseus and Circe were real? In the literal sense, I doubt it. However, a talented female poisoner who used her knowledge to lead natives to worship her as a demigod might have been living on an island. At some point in history, someone might also have learned that consuming snowdrop provided protection against certain diseases and poisons. A local hero might have known a thing or two about herbalism, stood up to a cruel poison-wielding witch, proved that he was resistant to her magic, and come to be known as the great-grandson of Hermes … and wouldn't that be cool? D

Copyright © 2015 by Matt Kaplan. From the forthcoming book *Science of the Magical: From the Holy Grail to Love Potions to Superpowers* by Matt Kaplan to be published by Simon & Schuster Inc. Printed by permission.

BASED ON HOMER'S DESCRIPTION, many experts think the "potent herb" Hermes gave Odysseus as a cure to Circe's potion was actually the snowdrop plant. Scientists have studied the plant and found that it contains properties that protect brain cells from damaging toxins.

WELLCOME LIBRARY, LONDON

CELESTRON

The World's Most-Loved Telescope Has Evolved

NexStar EVOLUTION

The First Schmidt-Cassegrain Telescope with Fully Integrated WiFi

Celestron's Most Innovative Technologies Plus New Upgrades

+ Control your telescope wirelessly with your smartphone or tablet via WiFi.
+ Integrated long-life lithium iron phosphate battery (LiFePO4) supports up to 10 hours of use without external power.
+ New features include USB charging port, adjustable accessory tray light, improved tripod, and completely redesigned mount.
+ Telescope automatically locates over 100,000 objects using Celestron's SkyPortal app.

CELESTRON SkyPORTAL™

Download the free Celestron SkyPortal app and start exploring today with or without NexStar Evolution!

Available on the App Store

Google play

DISCOVER MORE AT

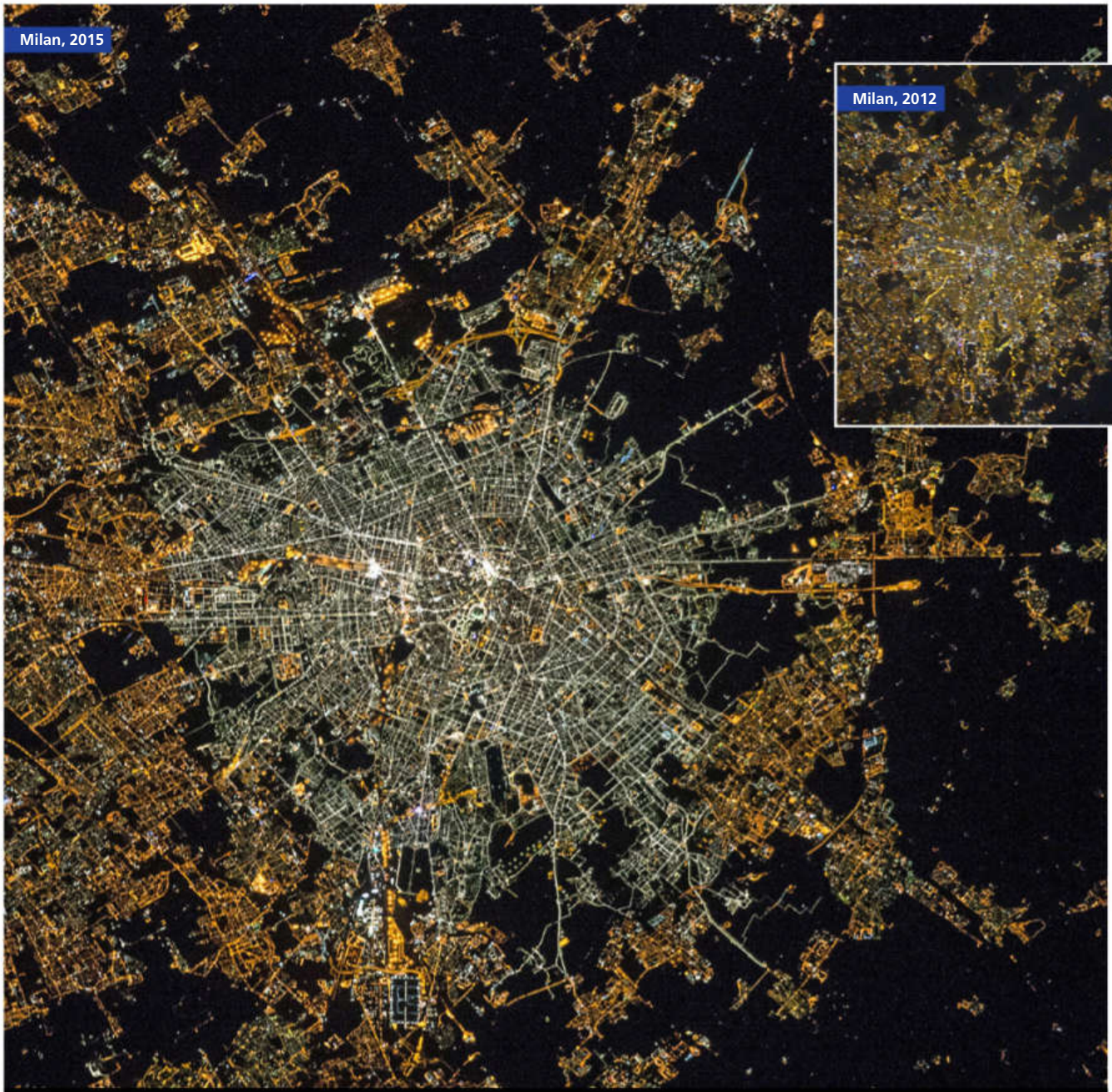
celestron.com

Powered by Astronomy magazine Astronomy

SPECIAL BONUS SECTION

OUT THERE

A Look at the Universe and All Its Wonders



OUTSHINING THE STARS

Light pollution, a glaring problem for astronomers, is getting worse. Due to innovations in LED technology, streetlights shine longer, use less energy and glow brighter and whiter than the venerable orange sodium vapor lamps. The difference is easy to see in these photos of Milan, Italy, taken by space station astronauts. Researchers are cataloging thousands of orbital photos to get a more accurate picture of light pollution growth. In the following pages, Eric Betz explores the issue further in "A New Fight for the Night," which appears courtesy of our sister publication, *Astronomy*. — ERNIE MASTROIANNI; PHOTO BY NASA/ESA

A New Fight for the Night

Blue LEDs may have warranted a Nobel Prize in physics, but the lights are bad news for astronomers.

BY **ERIC BETZ**

The afternoon skies were clear and blue like countless centuries of others in Chile's Atacama Desert when the blast rang out. The explosion shattered the silence and sent rock high into the thin Andean air. Some 70 controlled detonations would follow, removing millions of cubic feet of dirt to flatten the peak of Cerro Las Campanas for the nearly $1 billion Giant Magellan Telescope.

But this won't be the only high-dollar instrument in the Atacama Desert. Nearby, work has begun on the Large Synoptic Survey Telescope, designed to image the entire visible sky every few nights. To the north, Europeans are constructing their Extremely Large Telescope, which will one day be the world's largest.

Combined with the recently finished Atacama Large Millimeter/submillimeter Array, these projects will cost more than $4 billion. This incredible investment was lured by what is perhaps Chile's greatest natural resource — some of the darkest and driest skies on Earth. In this wasteland, the Milky Way casts shadows, taking its claim as the sky's most distinguishable feature.

But even here this princely sum isn't enough to stop the march of light into one of the last bastions of the night. Cities are expanding alongside tourism and mining. Workers are improving the north-south Pan-American Highway, where the government is building highway security checkpoints with hundreds of LED streetlamps and 15 toll plaza floodlights below telescopes on Las Campanas and nearby La Silla. Outside the Cerro Tololo Inter-American Observatory in La Serena on the Chilean coast, a new mine will operate 24 hours a day and run material directly to port.

Unlike the United States, Chile has a national dark-sky ordinance. Some of these new sites will be in direct violation of the law, but so far, that hasn't stopped their progress.

"We've got some work to do," says Chris Smith, the head of mission in Chile for the Association of Universities for Research in Astronomy. "There are a lot of cheap, not very good lighting fixtures being pushed for, and we're having trouble with LED signs that are going up."

Smith worked with the Chilean government in 2013 to craft a new lighting ordinance that limits total light

BRIAN BRADLEY

Low-pressure sodium streetlights in Flagstaff, Arizona, cast a yellow hue across the world's first International Dark Sky City as seen from Mars Hill, home to Lowell Observatory.

The green Comet Lovejoy (C/2014 Q2) passes below the Pleiades and away from the red California Nebula over La Silla, Chile. Nearby (center right), the Pan-American Highway casts an earthly hue.

levels as well as electronic billboards. The Chilean president signed the legislation, but bureaucratic holdups have stopped the law's implementation.

Smith says he's now trying to convince Chilean officials that their night sky is a national resource no less important than the minerals coming from the ground.

Around the world, the centuries-old problem of light pollution has been compounded by a sea change in lighting technology brought on by LED lights that spread their radiation across the electromagnetic spectrum. Their light is cheap, efficient, and low maintenance, making conversion an inevitable choice.

New light shields and filters have given astronomers hope that LEDs might become a good thing for dark skies in some communities, but that will require governments to adopt and then enforce aggressive new policies. To solve the new problems, advocates must take on the old.

TAMING THE BLUE

This march of progress began in 1882 on the streets of America's largest city. New York — where Thomas Edison unleashed his incandescent revolution of fuses, meters, and bulbs — completed its move from gas streetlights into the era of electricity less than a century ago.

The tens of thousands of lampposts in a stunning variety of shapes and technologies eventually gave the avenues their famous ephemeral glow. The rest of the country followed at a breathtaking pace.

But in homes and on streets, lights progressed relatively little in the many decades since electricity's first revolutionary leap.

That changed in the early 1990s when three Japanese researchers solved a puzzle that had confounded scientists for decades. Isamu Akasaki and Hiroshi Amano of the University of Nagoya, as well as Shuji Nakamura from Nichia Chemicals, wanted to create white LEDs.

Red and green already existed, but scientists had tried and failed to produce a bright blue LED. All three were needed to make a white light.

Laboring in the lab, they found new ways of growing specific crystals and mastered fresh techniques for controlling semiconductors.

The bulbs became ubiquitous, eventually occupying Christmas lights, television sets, and streetlights.

White LEDs now can last 100 times as long as incandescent bulbs and 10 times longer than fluorescent lights. LEDs are also orders of magnitude more efficient, which means low-power solar panels can help bring light to the more than 1 billion people who now live without it.

Los Angeles, which has long been known and loved by Hollywood filmmakers for its yellow-tinged, high-pressure sodium lit nightscape, recently converted its streetlights to LEDs. To the chagrin of some movie buffs, the

P. HORÁLEK/ESO

streets now have a dramatically whiter look. The city's Bureau of Street Lighting — operating under the slogan "Bright Lights, Safe Nights" — has now swapped in 165,000 LED lights and estimates saving millions of dollars every year. In 2013, New York City announced it would follow suit, putting in a mind-boggling quarter of a million LED streetlights. Small towns and major cities across America are doing the same.

"Their inventions were revolutionary," the Royal Swedish Academy of Sciences said in announcing the 2014 Nobel Prize in physics for the invention of blue LEDs. "Incandescent light bulbs lit the 20th century; the 21st century will be lit by LED lamps."

THE NIGHTMARE SPECTRUM

The blue LED revolution has many cities converting without a second thought, but scientists say there's good reason to pause.

Before LEDs, new types of bulbs doubled lighting efficiency in the United Kingdom in the second half of the 20th century. Yet the electricity used per person for lighting grew fourfold during the same period. When lights get cheaper, humans tend to use more of them and in new, innovative ways.

For decades, low- and high-pressure sodium lights have been a yellow-hued mainstay in many dark-sky communities and big cities. These lights confine themselves to a small band of the electromagnetic spectrum that astronomers easily can remove. In contrast, LEDs leave a large footprint across the spectrum. The now common blue bulbs are the worst offender.

Their light falls in what University of Hawaii astronomer Richard Wainscoat calls the "nightmare spectrum."

In lighting, color temperatures above 5,000 kelvin are considered "cool colors," like blue. "Warm colors" such as yellow fall around 3,000 K. Cities are turning to LEDs because of the large potential cost savings; however, the average 5,000 K streetlight emits a large amount of light in the bandwidth around 450 nanometers, where astronomers commonly observe. The light might not be an affront to the eye in an already well-lit area, but for the sensitive CCD cameras used by astronomers around the world, it's blinding.

Los Angeles recently converted from yellowish high-pressure sodium (top) to bright white LED streetlights (bottom), prompting complaints from some movie buffs fond of the city's distinct nightscape.

"The blue light really has to be suppressed; otherwise our view of the night in the future is going to be suppressed," Wainscoat says.

Like other communities around the world, Hawaiian cities are converting to LEDs. On the Hawaiian island of Maui, Wainscoat is worried new city lights might jeopardize the dark skies needed by the instrument he heads, Pan-STARRS.

The wide-angle telescope has the world's largest CCD camera and rapidly scans the entire visible sky in search of asteroids and comets in Earth's vicinity. A recent record-breaking night netted 19 asteroids — two that approach our orbit — in one run.

New York City, once at the forefront of electricity, is again playing a leading role adopting LEDs.

And, like Chile, it's not just science at risk. An economic impact study by the University of Hawaii estimated that about $168 million was spent on astronomy in the islands in 2012, creating some 1,400 jobs.

LAWS NOT ENFORCED

Hope lies across the water on Hawaii's Big Island, home to the world-famous dark skies of Mauna Kea, where officials plan to update their lighting ordinance this year. New LED streetlights there have filters that remove the blue light. Full-cutoff light shields make sure the light points at the ground instead of up and out, which spreads light pollution. Warmer amber-filtered LEDs would be better for astronomy, but the technology is still far too expensive.

"On the positive side, retrofits with

CLOCKWISE FROM BOTTOM LEFT: WILLIAM ZUBACK/DISCOVER; LOS ANGELES BUREAU OF STREET LIGHTING; NASA

ANDREW COOPER/W. M. KECK OBSERVATORY

Light pollution spreads out below Mauna Kea on the Big Island of Hawaii, which will soon be home to the more than $1 billion Thirty Meter Telescope.

LEDs present the opportunity to replace poorly shielded lights with fully shielded lights," Wainscoat says. "Anyone with any interest in astronomy should stay very vigilant about this — to make sure that only fully shielded LEDs are installed."

That's not happening now outside the public sector. "Enforcement of the ordinance is quite lax," Wainscoat says. "A Jack In The Box [restaurant] on the Big Island is treated like a Jack In The Box anywhere else."

The problem is worse away from the major dark-sky sites, where relatively few residents are pushing cities to shield new LEDs and cities aren't enforcing existing laws. Even many astronomers are not yet on the bandwagon. At the most recent American Astronomical Society meeting in Seattle — the so-called "Super Bowl of astronomy" — a session on light pollution drew mostly empty chairs.

Daniel Caton, director of observatories at Appalachian State University in North Carolina, told those in attendance that he's generally disappointed at the lack of protest by astronomers in their hometowns.

"It's fine to go off to Mauna Kea or Cerro Tololo, but when you get home, you have to live with it," Caton says. "Eventually, these orange bubbles of sodium vapor light are going to overlap."

A WHITE-LIGHT NIGHT

In 2010, German researchers found that light pollution's global reach is expanding by 6 percent each year with understudied but very real impacts on biology. Some 30 percent of vertebrates are nocturnal, and that number doubles for invertebrates. Ecologists worry about species like moths and bats — nighttime pollinators that many plants depend on.

Other scientists think entire ecosystems could be at risk. Early 2014 studies with light traps in New Zealand found insects were 48 percent more attracted to LED lamps, regardless of bulb color, than they were to high-pressure sodium bulbs. They concluded that the new technology will create a "white-light night" that increases the ecological impact of light pollution.

And humans aren't immune either. Breast cancer studies have found that tumor growth accelerates when artificial light disrupts the circadian clocks of our 24-hour day and night cycle. That process controls as much as 15 percent of human genes, which leads researchers to suspect other ill effects from photons falling on human retinas at night. A report put out by the American Medical Association even recommends reducing light pollution, limiting shift work, and avoiding excessive nighttime exposure to electronic media.

The psychological impact is harder to quantify. Scientists can't put numbers on what happens when millions of children are raised in interconnecting light bubbles with little reason to look up. *The First World Atlas of the Artificial Night Sky Brightness* in 2001 showed two-thirds of Americans and half of Europeans can no longer see the Milky Way. In fact, after the 1994 Northridge earthquake knocked out power in Los Angeles, many residents called emergency lines to report a "giant, silvery cloud" in the night sky.

THE DARK-SKY GOSPEL

James Lowenthal is a self-described global warming evangelist. He's also an astronomy professor at Smith College in Massachusetts, where many residents hold similar environmental views.

One night, Lowenthal was riding his bike home when the glaring lights of new housing at a recently redeveloped psychiatric hospital site caught his eye.

"I was confident because of the good lighting ordinance I had helped pass, any new development would comply," Lowenthal says. That was not the case.

He took photos of the noncompliant lights and showed them to the city council. His images drew gasps from the elected officials.

He discovered the developers had told city planners they wanted to give

Even partial shields on streetlights cause substantial glare. Full shielding casts light straight down and confines it to the immediate area.

their buildings a "village feel" and gained approval to install acorn-style streetlamps for acres and acres. When confronted with the illegality of their lights, the developers pointed out that the manufacturer had stamped "dark-sky rated" on the product.

"It's definitely not full-cutoff," he says. "It doesn't satisfy any of the requirements of the board's own code, but because it said 'dark-sky rated,' they approved it."

"Every planning board in the country must be dealing with this," Lowenthal says. "They're overworked. It's very easy for things to slip through the cracks."

The problem has gotten worse for advocates. Northampton appointed an energy officer to monitor efficiency, and he's pushing for LED streetlights to be installed around town. The 2006 lighting code says nothing about the new technology.

Lowenthal decided to fight for changes to the code he helped pass. But his fight has been acrimonious in the small town. He's met resistance while pointing to research that shows excess lighting can negatively impact human health and disturb wildlife while having little effect on public safety.

The astronomer gave a presentation to Northampton's city council in 2014 and pushed for shielding requirements on new LEDs and a lighting curfew that would force businesses to stop lighting empty parking lots at night. He gathered 40 signatures for a "Starry Skies" petition. The city's police chief, Russell Sienkiewicz, stood up in opposition during the meeting, saying that lighting is the second most important tool police have, behind more patrols.

"I would ask just for you to consider if good lighting is important," the chief said, according to the *Daily Hampshire Gazette*. "If you're a nurse or a clerk working late and you have to walk in a dark parking lot because you are [a] half-hour behind when a business is closed, would lighting be good for you? Would you feel comfortable?"

To his frustration, Lowenthal says even the police headquarters has illegal lighting, installed as a result of a recent overhaul.

Unshielded lights illuminate a parking lot of patrol cruisers — and the sky above — at the police department in Northampton, Massachusetts. The city's lighting ordinance requires shielding.

He hopes municipalities can learn from the example of Davis, California, where a relatively small group of citizens recently showed they could have an impact.

Following a pilot project that went unnoticed, the central California town moved forward with plans to replace 2,600 streetlights with LEDs at a cost of about $1.2 million. Over the course of 15 years, the city council anticipated saving more than three times their initial investment, much of which was offset by federal grant funds. It wasn't until workers installed the LED lights across most areas of Davis that the complaints started streaming in.

Residents said they hated the glare, the color, and losing the night sky. Enough people complained that Davis suspended the project and is now looking at alternatives. Lowenthal says officials should take note that it's much more expensive to replace streetlights twice.

"If the public rejects your plan, what are you going to do?" he says.

DIMMING THE DESERT

A similar battle has been brewing in Arizona. In Flagstaff, signs posted at city limits proudly declare the mountain town as the world's first "International Dark Sky City."

TOP: ROEN KELLY/DISCOVER. BOTTOM: JAMES LOWENTHAL

HARBOR FREIGHT

QUALITY TOOLS AT RIDICULOUSLY LOW PRICES

How Does Harbor Freight Sell GREAT QUALITY Tools at the LOWEST Prices?

We have invested millions of dollars in our own state-of-the-art quality test labs and millions more in our factories, so our tools will go toe-to-toe with the top professional brands. And we can sell them for a fraction of the price because we cut out the middle man and pass the savings on to you. It's just that simple! Come visit one of our 600 Stores Nationwide.

SUPER COUPON

20% OFF

ANY SINGLE ITEM

LIMIT 1 - Save 20% on any one item purchased at our stores or HarborFreight.com or by calling 800-423-2567. *Cannot be used with other discount, coupon, gift cards, Inside Track Club membership, extended service plans or on any of the following: compressors, generators, tool storage or carts, welders, floor jacks, Towable Ride-On Trencher, Saw Mill (Item 61712/62366/67138), Predator Gas Power Items, open box items, in-store event or parking lot sale items. Not valid on prior purchases after 30 days from original purchase date with original receipt. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

23547231

SUPER COUPON

FREE

WITH ANY PURCHASE

3-1/2" SUPER BRIGHT NINE LED ALUMINUM FLASHLIGHT

LOT 69052 shown
69111/62522/62573

$6.99 VALUE

LIMIT 1 - Cannot be used with other discount, coupon or prior purchase. Coupon good at our stores, HarborFreight.com or by calling 800-423-2567. Offer good while supplies last. Shipping & Handling charges may apply if not picked up in-store. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one FREE GIFT coupon per customer per day.

23336260

WOW SUPER COUPON

US GENERAL PRO

SAVE $238

26", 16 DRAWER ROLLER CABINET

- 1060 lb. Capacity
- 14,600 cu. in. of storage

LOT 61609
67831 shown

$319.99 ~~$369.99~~

comp at $558

23323252

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

72" x 80" MOVER'S BLANKET

HaulMaster

Customer Rating

LOT 66537 shown
69505/62418

SAVE 66%

$5.99

comp at $17.97

23298355

LIMIT 8 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

WOW SUPER COUPON

RAPID PUMP® 1.5 TON ALUMINUM RACING JACK

PITTSBURGH

SAVE $50

LOT 69252/60569 shown
68053/62160
62496/62516

- 3-1/2 Pumps Lifts Most Vehicles
- Weighs 32 lbs.

$59.99 ~~$89.99~~

comp at $109.99

23302304

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

Customer Rating

NEW

2500 LB. ELECTRIC WINCH WITH WIRELESS REMOTE CONTROL

BADLAND

SAVE $200

LOT 61258 shown
61840/61297/68146

$59.99

comp at $259.99

23318468

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

2.5 HP, 21 GALLON 125 PSI VERTICAL AIR COMPRESSOR

CENTRALPNEUMATIC

Customer Rating

SAVE $349

LOT 67847 shown
61454/61693/62803

$149.99

comp at $499

23340865

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

40 PIECE 1/4" AND 3/8" DRIVE SOCKET SET

- SAE and Metric

PITTSBURGH

Customer Rating

SAVE 60%

LOT 63015
61328/62843
47902 shown

$3.99

comp at $9.99

23308103

LIMIT 9 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

NEW

900 PEAK/ 700 RUNNING WATTS 2 HP (63 CC) 2 CYCLE GAS RECREATIONAL GENERATOR

LOT 60338/66619/69381 shown

SAVE $68

$99.99

comp at $168.97

23313900

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

WOW SUPER COUPON

1500 WATT DUAL TEMPERATURE HEAT GUN (572°/1112°)

SAVE 70%

LOT 62340/62546
96289 shown

drillmaster

$8.99 ~~$14.99~~

comp at $29.97

23302156

LIMIT 7 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

WOW SUPER COUPON

3-IN-1 PORTABLE POWER PACK WITH JUMP STARTER

CENTECH

SAVE 27%

LOT 60657 shown
38391/62306/62376

$39.99 ~~$49.99~~

comp at $54.97

23303351

LIMIT 5 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

12" SLIDING COMPOUND DOUBLE-BEVEL MITER SAW WITH LASER GUIDE

CHICAGO ELECTRIC POWER TOOLS

NEW

LOT 69684 shown
61776/61969/61970

Customer Rating

SAVE $264

$134.99

comp at $399

23322602

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

TWO TIER COLLAPSIBLE EASY-STORE STEP LADDER

SAVE 39%

- 225 lb. Capacity

Customer Rating

LOT 67514

$19.99

comp at $32.99

23325348

LIMIT 4 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

SUPER COUPON

60 LED SOLAR SECURITY LIGHT

Bunker Hill Security

LOT 62534/69643 shown

Customer Rating

SAVE 54%

Includes 6V, 900 mAh NiCd battery pack.

$31.99

comp at $69.99

23337706

LIMIT 3 - Good at our stores or HarborFreight.com or by calling 800-423-2567. Cannot be used with other discount or coupon or prior purchases after 30 days from original purchase with original receipt. Offer good while supplies last. Non-transferable. Original coupon must be presented. Valid through 2/13/16. Limit one coupon per customer per day.

- 100% Satisfaction Guaranteed
- Over 25 Million Satisfied Customers
- No Hassle Return Policy
- Lifetime Warranty On All Hand Tools
- 600 Stores Nationwide
- HarborFreight.com 800-423-2567

Light pollution's reach increases by 6 percent each year, leading researchers to predict that only a few patches of truly dark skies will soon exist in the U.S.

Percival Lowell built his observatory here more than a century ago atop Mars Hill, which now overlooks a city of about 60,000 people. The town is also home to the U.S. Navy's astronomy facilities.

In 2014, a developer tried to gain approval for a 714-bed student housing project right next to the Naval Observatory. The design did not violate the city's dark-sky ordinance, but doubled lighting near the facility, which also sits near Lowell.

The Flagstaff City Council approved the project despite a uniformed naval captain's briefing on the observatory's importance to America's defense. Hundreds wrote in protesting the development, and the project went down in defeat after nearby residents rallied a petition that forced a new vote backed by a supermajority of the council. The developer withdrew its request.

"This was very difficult to fight, probably because the developer said, 'You set the rules; we're following them,'" says Lowell Observatory Director Jeffery Hall. "I don't want to just be an ogre using the ordinance as a hammer."

Like chopping the head off the hydra, Hall doubts this development will be the last to challenge Flagstaff's dark skies. And the next threat already may be on the horizon. Long a major consumer of low-pressure sodium lights — the most dark-sky-friendly technology available — Flagstaff too is now testing a conversion to LEDs. The move took astronomers by surprise, and officials were similarly taken aback by the astronomers' protests. "Even our code is not ready to adapt to the recent changes in LED technology," Hall says. The debate prompted Lowell to host a conference on LEDs and light pollution last year and invite industry and government officials, as well as astronomers.

Lori Allen, who directs Kitt Peak National Observatory outside Tucson, Arizona, attended the conference because her facilities have seen the same problems. Kitt Peak has faced a funding crisis in recent years as it vies for cash with more modern instruments built in increasingly remote locations. NASA and the National Science Foundation only recently eased Allen's concerns by committing to pay for new instruments to carry out long-term projects on the mountain.

Growth across her border city has been swift, but Allen says the observatory's main foe lies farther away. Photos of sky glow captured since the 1950s predictably show Tucson's light bubble increasing, but at an amount that pales in comparison to the spread of Phoenix more than 100 miles (160 kilometers) away. Amazingly, a 2010 study found that Kitt Peak's dark skies were relatively constant going back to the 1970s due in large part to strict lighting ordinances. But as the city of Tucson begins converting to LED streetlights, it too must find a way to incorporate the new technology into existing regulations or risk losing night skies.

"All these cities are looking at these LEDs and seeing huge savings," Allen says. "We're not dead yet, and we've got some exciting projects over the next few years. We have a very bright future at Kitt Peak if we can keep the dark." D

Eric Betz *is an associate editor of* Astronomy. *Follow him on Twitter,* ***@ericbetz***

DATA: MARC IMHOFF OF NASA GSFC AND CHRISTOPHER ELVIDGE OF NOAA NGDC. IMAGE: CRAIG MAYHEW AND ROBERT SIMMON, NASA GSFC


ZZZZ
MEN
Less Pees, More Zzz's...
One of the signs of an aging prostate is an increased need to urinate, often in the middle of the night.
That's where The Prostate Formula can help. The Prostate Formula specifically supports:
Healthy Prostate Function
Free Urinary Flow
Healthy Prostate Size
In short? More time catching Zzz's, less times getting up to pee.
For coupons and more information: www.ProstateFormula.com
Now with Vitamin D & Ginger!
REAL HEALTH LABORATORIES
THE Prostate FORMULA with Saw Palmetto
ADVANCED FORMULATION
Specifically Supports:
Healthy Prostate Function*
Healthy Prostate Size*
Free Urinary Flow*
Healthy Sex Life*
LABORATORY QUALITY TESTED
3 MONTH SUPPLY
270 TABLETS DIETARY SUPPLEMENT
CVS/pharmacy
drug mart
DUANE reade
Harris Teeter Neighborhood Food & Pharmacy
kmart
RITE AID PHARMACY
Walgreens
These statements have not been evaluated by the FDA. This product is not intended to diagnose, treat, cure or prevent any disease.


March 2–11, 2016
Tour BALI and witness a TOTAL ECLIPSE
with Discover magazine
Experience a solar eclipse trip like no other in this equatorial paradise Indonesia. Immerse yourself in the festivities leading up to the Balinese New Year before watching the Moon block the Sun's light in a total solar eclipse. Your tour includes:
Balinese rituals that few ever witness
Stunning art and architecture, including visits to ancient temple gardens
Lectures and eclipse viewing guidance from Discover staff
And much more!
JOIN THE TRIP TODAY!
Visit www.discovermagazine.com/bali
SCIENCE FOR THE CURIOUS Discover MAGAZINE
TRAVEL QUEST international
P26339
William Cho (landscape); Mike Reynolds (eclipse)

First Look at the 2017 Total Eclipse

Excitement is building for the first total solar eclipse in the U.S. in 26 years.

BY **MICHAEL E. BAKICH**

A small percentage of people have experienced a total solar eclipse. Even fewer have seen one from the air. The photographer and some friends chartered a Dassault Falcon 900B jet from Bermuda to observe and record the event on November 3, 2013.

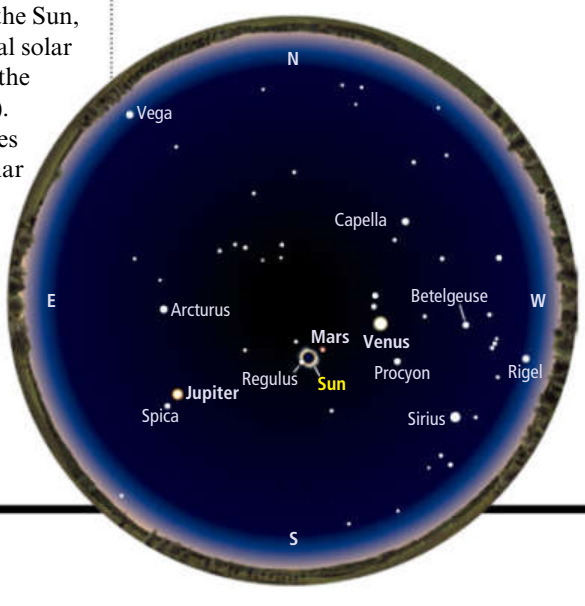
Drama is coming to the U.S. On August 21, 2017, Sun-watchers along a line from Oregon to South Carolina will experience nature's grandest spectacle: a total solar eclipse. It's likely to be the most viewed sky event in history. That's why even now, nearly two years before the eclipse, astronomy clubs, government agencies, cities, and even whole states are preparing for the unprecedented onslaught of visitors whose only desire is to experience darkness at midday.

This will be the first total solar eclipse crossing the continental U.S. in 38 years (totality touched Hawaii on July 11, 1991). The last one occurred February 26, 1979. Unfortunately, not many people saw it because you had to be in (or travel to) a narrow path crossing one of just five states in the Northwest, and that winter's weather for the most part was bleak along the path of totality. Before that eclipse, you have to go back to March 7, 1970, a total solar eclipse that moved up the East Coast, again occurring in a scant five states.

THE BASICS

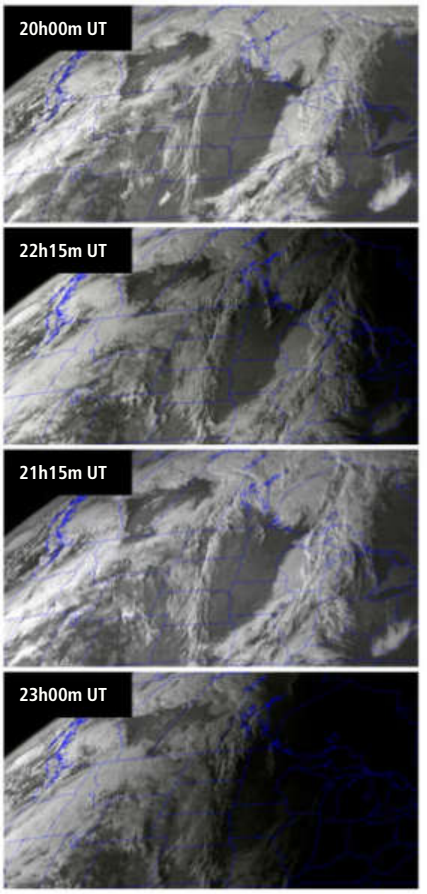
I like to think of total eclipses as examples of sublime celestial geometry. Each one is an exact lineup of the Sun, the Moon, and Earth (for a total solar eclipse) or the Sun, Earth, and the Moon (for a total lunar eclipse). And although total solar eclipses occur more often than total lunar ones, more people — actually, pretty much everyone — have seen a total eclipse of the Moon. Few, on the other hand, have seen a total solar eclipse.

The reason is quite simple: We live on Earth, and it's our perspective that interacts with the geometry of these events. During a lunar eclipse, anyone on the night side of our planet under a clear sky can see the Moon passing through Earth's dark inner shadow. That shadow, even as far away as the Moon, is quite a bit larger than the



This sky chart shows the Sun near the time of greatest eclipse along with some of the bright celestial objects you may be able to spot during totality. The Sun stands before the constellation Leo the Lion. Magnitude 1.3 Regulus (Alpha [α] Leonis) lies 1.3° east of the Sun, where sharp-eyed observers under a perfect sky may spot it. Other objects to look for are magnitude –4.0 Venus (36° west-northwest of the Sun), magnitude –1.8 Jupiter (51° east-southeast), magnitude –1.5 Sirius (Alpha Canis Majoris, 57° west-southwest), and magnitude 0.1 Rigel (Beta [β] Orionis, 61° west). Mercury (10.5° southeast) and Mars (8.3° west-northwest) will glow at magnitudes 3.3 and 1.8, respectively, so they will remain invisible.

TOP: BEN COOPER/LAUNCHPHOTOGRAPHY.COM. BOTTOM: RICHARD TALCOTT AND ROEN KELLY/DISCOVER



The 13th NOAA Geostationary Operational Environmental Satellite took this series of images during the partial solar eclipse October 23, 2014. The shadow moved over Alaska, western Canada, and the far northwestern United States.

This photo is a digital multiple-exposure of the sequence of the November 14, 2012, total solar eclipse beginning shortly after sunrise as seen from Queensland, Australia.

Moon, so it takes our satellite some time to pass through it. In fact, if the Moon passes through the center of Earth's shadow, the total part of the eclipse can last as long as 106 minutes. Usually totality doesn't reach that duration because the Moon passes either slightly above or below the center of the shadow our planet casts.

Conversely, the Moon and its shadow at the distance of Earth are much smaller; so small, in fact, that the shadow barely reaches our planet's surface. Anybody in the lighter outer region of the shadow (which astronomers call the penumbra) will see a partial solar eclipse.

The lucky individuals under the dark inner shadow (the umbra) will *experience* — a much better word than "see" — a total solar eclipse. Sometimes, only the Moon's penumbra falls on Earth, and the eclipse is partial everywhere. Not in August 2017.

A question people often ask is, "Isn't the Sun a lot bigger than the Moon, so how does the Moon cover it so exactly?" Yes, the Sun's diameter is approximately 400 times larger than that of the Moon. What a coincidence that it also lies roughly 400 times farther away. This means both disks appear to be the same size.

Regarding timing, all solar eclipses happen at New Moon. Unless the Moon lies between the Sun and Earth, it can't block any of our star's light. The only lunar phase when that happens is New Moon.

But why doesn't a solar eclipse happen at every New Moon? The reason is that the Moon's orbit tilts 5° to the plane formed by Earth's orbit around the Sun, which astronomers call the ecliptic (because that's the only place eclipses can occur).

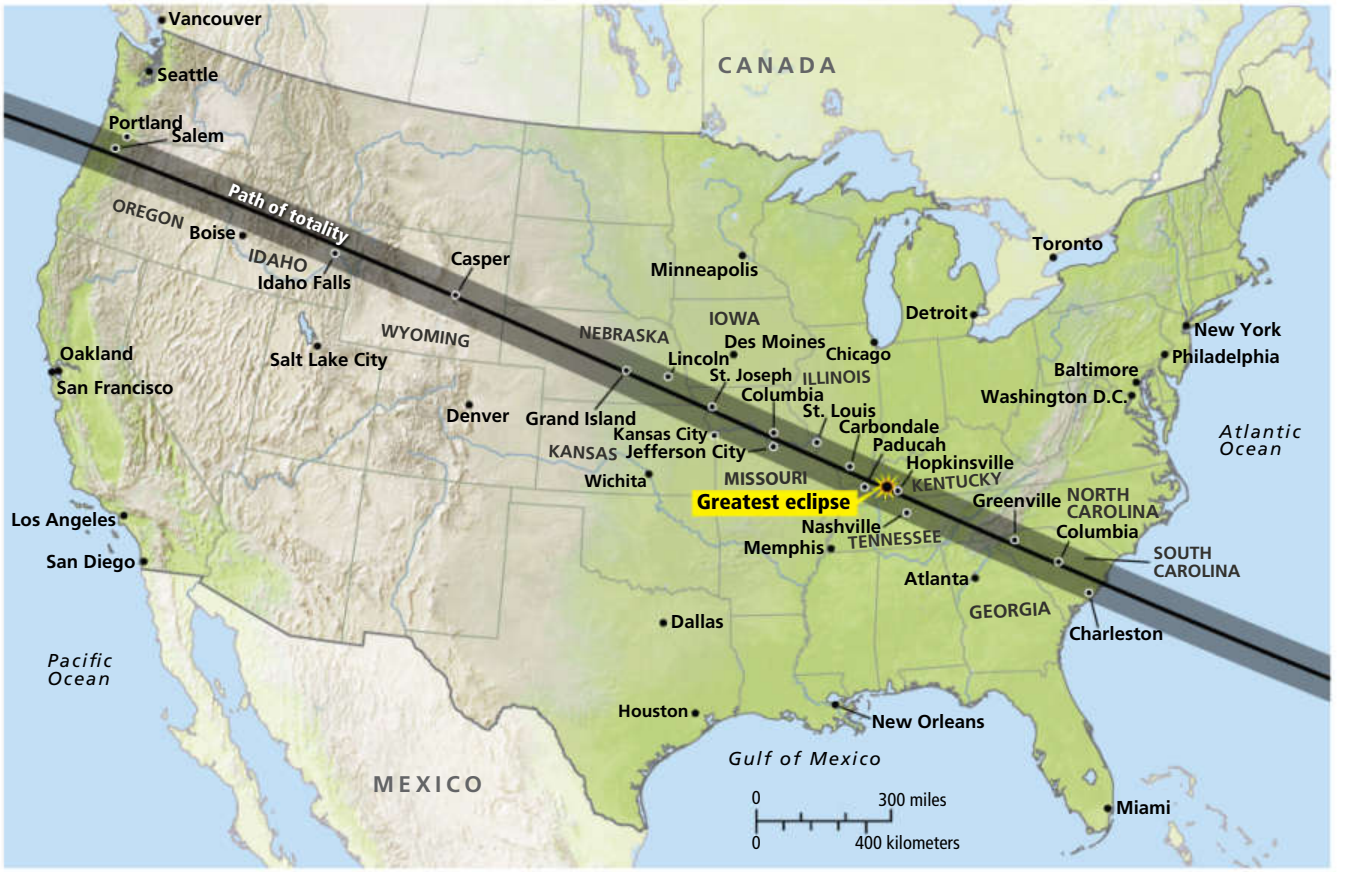
Most of the time, our satellite is either north or south of the ecliptic. But during each lunar month, the

LEFT: NASA/NOAA/SSEC. RIGHT: BEN COOPER/LAUNCHPHOTOGRAPHY.COM

REWARD
$10,000.00
"The Theories of Relativity, Special Relativity, String, Steady State and Nebula Hypothesis' (Accretion) have all been disproven. You're invited to disprove "The AP Theory". So confident are we that "The AP Theory" most logically describes the formation of water and our solar system and how our atmosphere is being held down without gravity in the most logical way that we're offering a $10,000.00 REWARD to the first person to disprove it. Must include an example in nature (on Earth) and a description of a successful experiment.
READ: www.aptheory.info
COMMENT:
aptheory@aptheory.info
no purchase necessary

Better Way To Sleep
PURE COTTON KNIT TeePJs™
Tee-PJs are not ordinary nightshirts. They are made with a special soft cotton knit that moves as you move for the ultimate in sleeping and lounging comfort.
★NO BIND ★NO BUNCH
★NO BUTTONS
★NO SIDE SEAMS
QUALITY MADE IN THE USA!
TeePJs – the most comfortable sleeper you've ever worn or your money back!
Great for Ladies, too.
COLORS: White or Soft Blue.
SIZES: To fit 90-300 lbs.
Specify man/lady and height/weight for a perfect fit.
Add $2 per nightshirt for XXXL.
$26.95 ea. 2 for $49.90 (Save $4)
Long sleeve style (not shown):
$30.95 ea. 2 for $57.90 (Save $4)
S&H: add $6.95 for 1 or $8.95 for 2
Send check or use Visa/MC/Discover/AMEX
Cotton Comforts Since 1955
Wittmann Textiles - Dept. 421
11570 SE Dixie Hwy, Hobe Sound, FL 33455
(Ship to FL add tax) 1-800-890-7232
HUGE SELECTION OF COTTON SLEEPWEAR, ROBES AND UNDERWEAR - www.nightshirt.com

DARKNESS CROSSES THE UNITED STATES



The path of the Moon's umbral shadow across land begins in Oregon and ends in South Carolina. Numerous large cities lie within easy reach of the center line. The longest duration of totality — 2 minutes and 41.6 seconds — occurs in and around Giant City State Park in Illinois.

Moon's orbit crosses that imaginary plane twice. Astronomers call these intersections nodes.

Solar eclipses only occur when the Sun and the Moon lie at the same node. Unfortunately, during most lunar months, the New Moon lies either above or below one of the nodes when the Sun is there, and no eclipse happens. On average, a total solar eclipse occurs somewhere on Earth about once every 16 months.

But the average length of time between two total solar eclipses at a specific location on Earth is much longer: 330 years in the Northern Hemisphere and 550 years for locations south of the equator.

The difference between the hemispheres is due to two factors: 1) More eclipses occur during summer months (more hours of daylight); and 2) the Northern Hemisphere lies farther from the Sun during its summer, making our daytime star a smaller target (hence, easier to cover).

The maximum length of totality also varies from one eclipse to the next. The reason comes from the fact that Earth is not always at the same distance from the Sun and the Moon is not always the same distance from Earth. The Earth-Sun distance varies by 3 percent and the Moon-Earth distance by 12 percent.

The result is that the Moon's apparent diameter can range from 7 percent larger to 10 percent smaller than the Sun. A bigger apparent size for the Moon and a smaller one for the Sun equals a longer totality. But a Moon that looks smaller and a Sun that appears larger means that you'll experience a shorter time in the dark.

According to Belgian astronomer Jean Meeus, the maximum duration of totality from 2000 B.C. to A.D. 3000 is 7 minutes and 29 seconds. That eclipse will occur July 16, 2186, so don't get too anxious.

The length of totality during the August 21, 2017, eclipse won't be nearly that long.

Its duration will vary according to your location. Where the Moon's umbra first touches land, at Government Point, Oregon, totality lasts 1 minute and 58.5 seconds. The maximum duration, 2 minutes and 41.6 seconds, occurs just south of Carbondale, Illinois.

ROEN KELLY/DISCOVER

GET *DISCOVER* FOR YOUR DIGITAL DEVICE

Get all the cutting-edge science, technological breakthroughs, and medical advances you enjoy for your tablet or mobile device.

Stay up to date on:

- The latest in astronomy and space science, from distant galaxies to our own solar system.
- The newest discoveries in the search for ancient civilizations and human origins.
- The amazing medical innovations that will change the way we live, heal, and age.

Take *Discover* wherever you go!

Subscribe today at www.DiscoverMagazine.com/digital

Powered by Zinio™, digital editions are available on PC; Macintosh; Android™; iPad®; iPhone®; and Windows 8.

Zinio is a registered trademark of Zinio, LLC. Android is a trademark of Google Inc. iPad and iPhone are trademarks of Apple Inc., registered in the United States and other countries. Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

P24640

As totality was ending July 22, 2009, this imager captured three exceptionally nice Baily's beads, which form when light from the Sun's disk passes through valleys on the Moon's edge.

Whether you observe the Sun with or without a telescope, you must use an approved solar filter. Here, the author's wife, Holley, attached a filter to the front of the telescope.

The two most exciting words in science may be, "Diamond ring!" This shot, taken at the beginning of totality July 11, 2010, shows why that phenomenon received its popular name.

IT'S ALL ABOUT TOTALITY

Everyone in the contiguous U.S. will see at least a partial eclipse. In fact, if you have clear skies on eclipse day, the Moon will cover at least 48 percent of the Sun's brilliant surface. And that's from the northern tip of Maine. But although our satellite covering part of the Sun's disk sounds cool, you need to aim higher.

Likening a partial eclipse to a total eclipse is like comparing almost dying to dying. If you are outside during a solar eclipse with 48 percent coverage, you won't even notice it getting dark. And it doesn't matter whether the partial eclipse above your location is 48, 58, or 98 percent. Only totality reveals the true celestial spectacles: the two diamond rings, the Sun's glorious corona, 360° of sunset colors, and stars in the daytime. But remember, to see any of this, you must be in the path.

That said, you want to be close to the center line of totality. The fact that the Moon's shadow is round probably isn't a revelation. If it were square, it wouldn't matter where you viewed totality. People across its width would experience the same duration of darkness. The shadow is round, however, so the longest eclipse occurs at its center line because that's where you'll experience the lunar shadow's full width.

YES, WE'RE SURE

This event will happen! As astronomers, some of the problems we deal with are due to the uncertainty and limited visibility of some celestial events. Comets *may* appear bright if their compositions are just so. Meteor showers *might* reach storm levels if we pass through a thick part of the stream. A supernova as bright as a whole galaxy *may* be visible, but you need a telescope to view it. In contrast to such events, this solar eclipse will occur at the exact time astronomers predict, along a precisely plotted path, and for the lengths of time given. Guaranteed. Oh, and it's a daytime event to boot.

After the 2017 event, the next total solar eclipse to track across the continental U.S. occurs April 8, 2024. It's a good one, too. Depending on where you are (on the center line), the duration of totality lasts at least 3 minutes and 22 seconds in eastern Maine and stretches to 4 minutes and 27 seconds in southwestern Texas.

After that eclipse, it's a 20-year wait until August 23, 2044 (and, similar to the 1979 event, that one is visible only in Montana and North Dakota). Total solar eclipses follow in 2045, 2052, and 2078. But it's 2017 that's causing all the excitement now. Stay tuned to *Astronomy* and Astronomy.com for much more information about this event. Future stories will discuss trip planning, how to observe the event, top locations for activities and viewing, and much more. We'll keep you informed so that you can approach the eclipse without a shadow of doubt. D

Michael E. Bakich *is a senior editor of* Astronomy. *He will be conducting a massive public viewing party for the eclipse in St. Joseph, Missouri. Visit* ***www.fpsci.com*** *for details.*

CLOCKWISE FROM TOP LEFT: BERT HALSTEAD; LES ANDERSON; MICHAEL E. BAKICH

CLASSIFIEDS

TRAVEL

AMAZON RAINFOREST
Award-winning lodge in Tamshiyacu-Tahuayo Reserve, shown to have the world's greatest diversity of primates. Customized itineraries, daily departures. 1-800-262-9669.
Visit: www.perujungle.com

DO YOU HAVE A PRODUCT, OR SERVICE YOU WANT TO PROMOTE TO OVER **6 MILLION READERS?**

ADVERTISE HERE

CONTACT JAMIE RINEHART
FOR INFORMATION, RATES, AND THE NEXT AVAILABLE ISSUE

888-558-1544 ext. 628

SMENI@DISCOVERMAGAZINE.COM

SOLO OR 2 PERSON PLAY!

DEVELOPS SPATIAL SKILLS!

ZOBRIST CUBE™

20,000 Puzzles in a Box!

33 POLYCUBE PIECES & 52 PAGE CODE BOOK

Never get bored by a cube assembly puzzle again. Each code in the code book specifies a different set of pieces that assemble into a cube. The codes are sorted by difficulty from easy to hard. There are even two sections of simple puzzles for children. Extra pieces allow two player competition, all packed in a beautiful box.

1 (855) 962-7478 www.ZobristCube.com Ages 6 - Adult

STELLAR SCIENCE

The world's best-selling astronomy magazine delivers top-notch space and science coverage to your doorstep.

GET 12 ISSUES FOR JUST $29.95 – PLUS EXCLUSIVE ONLINE BENEFITS!

SUBSCRIBE TO *ASTRONOMY* TODAY!

HOW TO ORDER:

ONLINE
Go to Astronomy.com/offer and enter the code in the lower right.

CALL
800-533-6644
Monday-Friday 8:30 a.m.-4:30 p.m. CT.
Outside the U.S. and Canada call 262-796-8776 ext. 661.
Please have your credit card ready.

*Savings based on annual newstand price.

P26620

A5BRA

The Evolutionary Timeline, Retooled

A chance discovery reveals the first "makers" predate our genus.

BY **HILLARY WATERMAN**

Research team member Sammy Lokorodi (left) discovered partly exposed stone tools that were made about 3.3 million years ago, the oldest ever found. Archaeologist Sonia Harmand and a colleague (above) document the tools *in situ* at the Lomekwi 3 site in northern Kenya.

Thanks to a wrong turn, a stroke of luck and keen eyes, husband and wife research partners Sonia Harmand and Jason Lewis of Stony Brook University could rewrite our understanding of tool use among hominins. With their team from the West Turkana Archaeological Project, the pair have found evidence that a species predating the genus *Homo* may have made the first stone tools.

In July 2011, Harmand and Lewis and their colleagues were scouting for sites in the area around northern Kenya's Lake Turkana. There are no roads in this remote region, so Harmand was forced to drive in dry creek beds while Lewis navigated with a GPS device. It's all too easy to become disoriented in this kind of terrain; at a certain juncture where the GPS indicated a right turn, she mistakenly went left. They soon found the way blocked by bushes. Unable to drive farther, they climbed a small hill to get their bearings. From the top of the rise, the team gazed down on what Harmand describes as a uniquely beautiful landscape.

"I felt certain it contained hidden areas waiting to be explored," she says. Everyone fanned out to investigate. "We were only 10 people, working far from each other with walkie-talkies. Around 9 in the morning, we had a call from our local Turkana team member, Sammy Lokorodi. He said, 'You should come where I am because I think I've spotted something very interesting.'"

He found stone tools sticking out of an eroding creek bed. The surface above had a dark, weathered patina, but the areas around the rocks were light, suggesting they had been only recently exposed. Harmand knew at once this was an important find because the layers in which the tools were embedded were dated to more than 2.7 million years old.

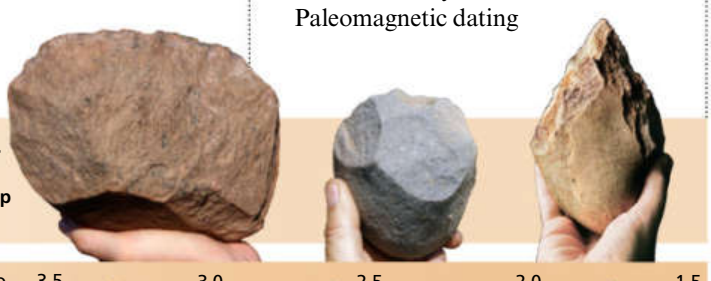
Paleomagnetic dating — matching magnetic properties in the sediments surrounding a fossil or artifact to ancient reversals in the Earth's magnetic poles to determine age — later determined the tools had to have been made 3.3 million years ago. Despite the tools' simple form and huge size, some almost 8 inches across, the angle and patterns on the rocks' edges showed repetitive strikes that could not have resulted from erosion or other natural processes. Publishing the discovery in *Nature* in May, Harmand and Lewis dubbed the assemblage the Lomekwi 3, after the area where the tools were found.

OLDER THAN OLDOWAN

Until now, the Oldowan, named by Louis Leakey after Olduvai Gorge in northern Tanzania, was the earliest known stone tool assemblage. Oldowan tools have been found at sites around eastern, southern and central Africa; the oldest, at 2.6 million years, comes from Gona, Ethiopia. Averaging about 2 to 4 inches across, they were made using what paleoanthropologists call a "free hand" technique: A core is held in one hand and repeatedly struck

STONE TOOL TECHNOLOGY

As hominins evolved, so did their tools, becoming smaller, easier to grip and more complex.



TOP, ALL PHOTOS: MPK-WTAP. TOOL PHOTOS FROM LEFT: MPK-WTAP; JAVIER TRUEBA/MSF/SCIENCE SOURCE (2)

The Lomekwi 3 tools, like this partially excavated specimen, were larger and cruder than later implements but bear unmistakable signs of intentional fabrication.

with a round hammerstone held in the other hand to release sharp flakes. Both hands are active and coordinated in their actions.

In contrast, the earlier Lomekwi 3 toolmakers set the cores on larger rocks and struck them with the hammerstone from above. The Lomekwian tools are more than twice as large as Oldowan tools. Although they bear the unmistakable marks of intentional shaping, they are much cruder in form. Harmand believes the Lomekwi 3 tools represent a precursor to free-hand knapping.

While the researchers could definitively state the tools' age and method of manufacture, a larger mystery looms: Who made them?

In the 1960s Leakey proposed that *Homo* was the first toolmaker, which remains the accepted view. The very name of the oldest known member of our genus, *Homo habilis*, translates to "handyman" in reference to tool making. Although the fossil record for the first members of the *Homo* genus is poor, the earliest definitive *H. habilis* specimen is about 2.4 million years old. The brain of *H. habilis* was considerably smaller than that of modern humans, but larger than that of *Australopithecus*, the family widely viewed as its ancestors.

Australopithecines proliferated in the rift valleys of eastern Africa about 2.6 million to 4 million years ago. The well-known *Australopithecus afarensis* fossil we call Lucy, for example, lived a little over 3 million years ago in Ethiopia's Afar region, roughly 700 miles northeast of Lake Turkana. Earlier this year, researchers working at another site in the Afar region found the oldest known *Homo* fossils: Dated to 2.8 million years old, the fragmentary jaw and teeth, not yet formally assigned to *H. habilis*, suggest *Homo* emerged 400,000 years earlier than currently thought. But even with this revised timeline for our own genus, the Lomekwi 3 tools still predate any known species of *Homo* by more than half a million years.

The list of prime suspects features several species of australopithecine, but Harmand and Lewis also have their eye on *Kenyanthropus platyops*, a fossil discovered in 1998 very close to the Lomekwi 3 site. *Kenyanthropus*, at 3.3 million years old, is contemporaneous with the Lomekwi 3 toolmakers — probably not a coincidence. Lewis says the answer is still unclear and that there may be more fossils yet to be found. For now, the most tantalizing clue to the mystery may have come from a separate team of researchers working in a lab far from Lomekwi.

INHERITING A TOOLBOX OF TRAITS

Enter Matt Skinner and Tracy Kivell of the University of Kent, who discovered an unexpected shared trait in humans and australopithecines. Using a high-resolution CT scan — think of it as a 3-D X-ray — their team documented that human hand bones show increased internal density in response to certain types of stress and repetitive motion, particularly that associated with the manufacture and use of stone tools. They detected these same modifications in a skeleton of *A. africanus*, another australopithecine that roamed South Africa between 2 million and 3 million years ago.

Skinner, whose team published their findings in January in *Science*, believes australopithecines could make stone tools. Moreover, his findings suggest that natural selection favored the grasp, coordination, cognitive skills and hand shape needed to create these early tools. The tools — and the act of making and using them — may have shaped us, too, not just the other way around.

"Researchers have long speculated that there would be tools 'older than the Oldowan,'" says Skinner, "and it is fantastic that this evidence has now been found and published. Of course, it is consistent with our finding, and that is reassuring for us."

"The good discoveries are the ones that raise more questions," says Lewis. And the Lomekwi find raises many; it also definitively resets the archaeological record with respect to hominin tool making. Now the big question is: Has our genus been around much longer than previously thought, or did an earlier species of "makers" actually get a head start on the road to Homo?

Hillary Waterman *is a science writer based in Maine.*

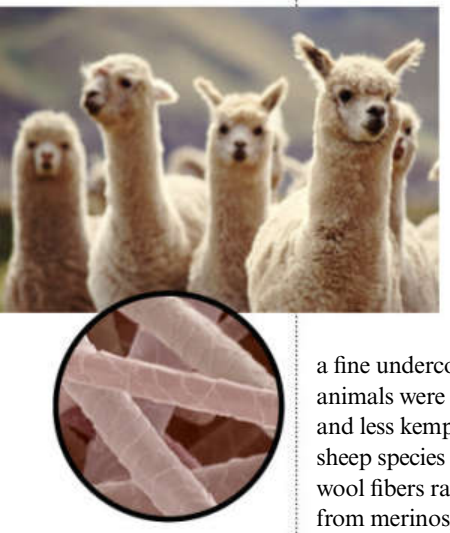
RAINER LESNIEWSKI/SHUTTERSTOCK

20 Things You Didn't Know About ...

Wool

BY **MARGARET SHAKESPEARE**

1 Many of us associate wool with sheep, but other mammals — including alpacas, camels and goats — also produce fibers that can be twisted into yarn and then textiles. **2** It's possible humans started making wool after noticing that, as the fibrous hairs were scraped from the hide of an animal, they twisted together easily into lengths. **3** Wool fibers — made mostly of alpha-keratin, which is found in all mammalian hair as well as horns and claws — stick together easily. The cells of their outer layer, or cuticle, have evolved to overlap like tiny shingles, creating spots for one fiber to catch on another as they are twisted. **4** Clothing and other items made of wool have been found throughout much of the ancient world, from 3,400-year-old Egyptian yarn to fragmentary textiles unearthed in Siberian graves dating from the first century B.C. **5** The process of making wool fabric from fibers was rough going at first — literally. Wild and early domesticated sheep have a bristly overcoat called the kemp and a fine undercoat of wool called the fleece. Over time, animals were selected for more fleece, with finer fibers, and less kemp. The more than 200 domesticated sheep species today are mostly kemp-free. **6** Modern wool fibers range from a fine 16 microns in diameter, from merinos, to 40 microns. **7** That itch from your warm winter woolies? Most likely it's sensitivity to thicker (and coarser) fiber diameter or fiber ends, not a wool allergy, which is practically unknown. **8** Less lush pastures — such as in a drought — can produce finer fibers, with smaller diameters. **9** Wool has been a valuable commodity across cultures and centuries. When Richard I (the Lionhearted) was captured in 1192, Cistercian monks paid their part of the ransom to the Holy Roman emperor in 50,000 sacks of wool (a year's clip). **10** Wool has stood in for even more precious fabrics: In 18th-century Norway, when the king forbade the wearing of silk by commoners, farmers opted for imported worsted wool fabric, which had a similar sheen. **11** Besides clothing, wool has quite a few industrial uses, from piano dampers to absorbent pads for those baaaaad oil spills. **12** Out on some Montana roadsides, woolen silt fences and erosion-control blankets are cropping up, according to Rob Ament of the Western Transportation Institute, which adapted the practice from New Zealand colleagues. **13** Wool has the right properties for the job because it's a lightweight ground covering that allows seedlings to grow right through it. **14** Wool is also biodegradable. It breaks down slowly, fertilizing the plants with a generous nitrogen content of a whopping 17 percent compared with the 6 percent nitrogen in commercial turf products. And it is water-retentive. **15** In a seeming paradox, wool can absorb and repel water simultaneously. **16** The outer surface of wool fiber is made up of fatty acid proteins and does not absorb liquid. However, structural features in the fiber's interior, called salt linkages, can sop up copious amounts of moisture in vapor form. **17** In short, wool hates liquid but loves vapor. **18** But wait, there's more: With a high natural ignition point of about 1,382 degrees Fahrenheit, wool is fire-resistant. And unlike nylon and polyester, wool does not drip or melt when it does catch fire. **19** These qualities recently attracted the interest of the U.S. Army, which is researching wool's potential in clothing designed to protect combat troops from explosive blasts. **20** We can thank wool for a different kind of explosion — one we actually want. Inside most baseballs, including those used in Major League Baseball, you'll find layers of tightly wound wool yarn: Each ball contains about 370 yards of the wool windings, which provide resilience to withstand the crushing impact of a batter's hit off high-velocity pitches. D



Sheep (top), alpaca (above) and some other animals have scalelike patterns on the outer layer of each hair (inset) that allow the fibers to be twisted together to create yarn and, ultimately, textiles valued the world over for their unique properties.

Additional reporting by ***Gemma Tarlach****.*

DISCOVER (ISSN 0274-7529, USPS# 555-190) is published monthly, except for combined issues in January/February and July/August. Vol. 36, no. 9. Published by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612. Periodical postage paid at Waukesha, WI, and at additional mailing offices. POSTMASTER: Send address changes to DISCOVER, P.O. Box 37807, Boone, IA 50037. Canada Publication Agreement # 40010760, return all undeliverable Canadian addresses to P.O. Box 875, STN A Windsor, ON, N9A 6P2. Back issues available. All rights reserved. Nothing herein contained may be reproduced without written permission of Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612. Printed in the U.S.A.

FROM TOP: PETE OXFORD/MINDEN PICTURES/GETTY IMAGES; DON MASON/CORBIS; SUSUMU NISHINAGA/SCIENCE SOURCE

Sadigh Gallery
ANCIENT ART, INC.

AUTHENTIC ANCIENT ARTIFACTS & COINS AT AFFORDABLE WHOLESALE PRICES

TO PLACE AN ORDER OR TO RECEIVE A FREE CATALOG, CALL US TOLL FREE AT 1(800)426-2007

© SADIGH GALLERY ANCIENT ART, INC.
303 5TH AVE, SUITE 1603
NEW YORK, NY 10016
TOLL FREE (800) 426-2007
PHONE (212) 725-7537
FAX (212) 545-7612
www.sadighgallery.com
info@sadighgallery.com

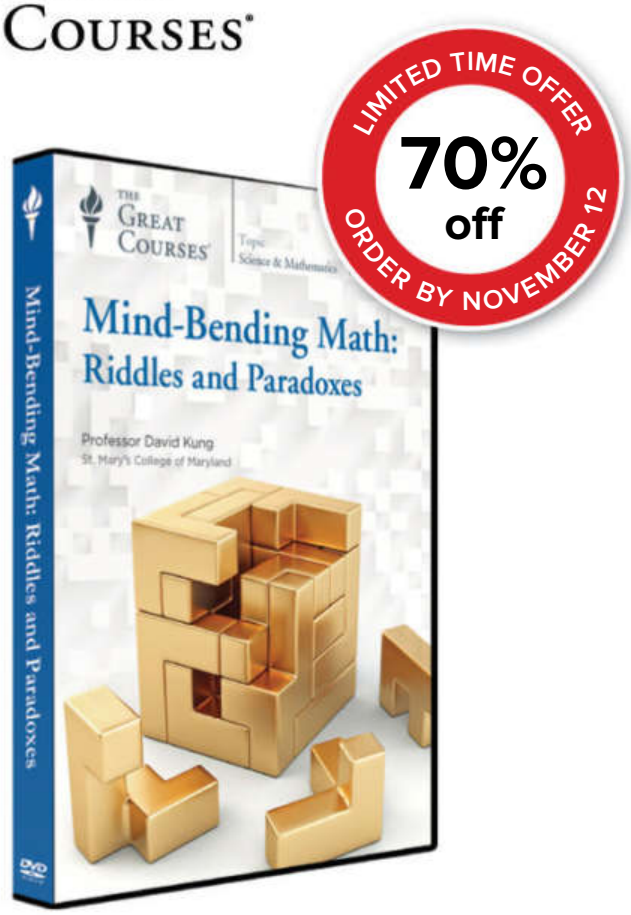
22092 European Marble Virgin Mary. 12" x 3" 1800's A **$450**
23222 Egyptian Lapis scarab amulet. 1" 2040-1786 BC.....**$100**
24221 Greek Bronze sphinx. 3 ½" x 2 ½" 400 BC.....**$2,500**
25960 Holy Land Terracotta oil lamp with Menorah. 4 ½" 100 BC-100 AD.....**$800**
25983 Egyptian Mummy beads necklace & earrings. 29" 600 BC **$120**
25985 Near Eastern Lapis lazuli inlays redesigned in an adjustable modern clad silver cuff bracelet. 3000 BC-1900's AD.....**$100**
26195 Holy Land Terracotta oil lamp. 2 ½" x 4" 100 AD.....**$80**
27672 Greek Silver Alexander the Great tetradrachm designed in a modern circular vermeil pendant setting. 1" 336-323 BC.....**$700**
29304 Byzantine Bronze cross pendant with the Madonna and Child, back with etched cross. 2" 600-900 AD.....**$400**
30608 Egyptian Bronze ankh pendant. 1 ½" 600 BC.....**$120**
30708 Egyptian Golden amber colored mold-blown glass with the head of Hathor, Goddess of joy. 4" x 1 ½" 100 BC.....**$350**
31418 American Silver Atocha shipwreck coin. 1 ¼" 1622 AD.**$400**
31442 Near Eastern Lapis lazuli inlays on a modern clad silver necklace with small red accent beads. 22" 3000 BC-1900 AD..**$120**
32640 Holy Land Lapis lazuli inlays set into a silver cross pendant setting with intricate filigree work. 3" 1800's AD.....**$100**
32666 Holy Land Lapis lazuli silver Star of David. 2" 1800's AD..**$100**
32833 Roman Bronze owl pendant. 2" 100-300 AD.....**$300**

34687 Greek Terracotta vessel with a rider on horseback on one side, two Kings holding staffs on the other. 5" x 7 ½" 400 BC..**$2,500**
35364 Greco-Roman Bronze medical bone drill. 7" 100 AD.....**$90**
36415 Egyptian Faience Ushabti. 5 ¼" 663-525 BC.....**$600**
39172 Egyptian Soapstone scarab. 1 ½" 715-332 BC.....**$120**
40249 Holy Land Bronze First Crusaders' cross pendant with the five wounds of Christ. 2" 1096-1099 AD.....**$100**
40318 Byzantine Gold coin of Michael VII. 1" 1071 AD.....**$1,200**
41066 Pre-Columbian Mayan terracotta drinking vessel with seated warriors on both sides. 7 ¼" x 3 ¾" 600-900 AD.....**$1,200**
41881 Greek Wooden Saint Nicholas icon. 6" x 7 ½" 1900 AD..**$500**
42703 Asian Large green jade Buddha seated in Dhyanasana on a lotus base. 7" x 13 ½" 1300 AD.....**$3,000**
43017 Greek Bronze sword. 22" 400 BC.....**$1,200**
43352 Sumerian Terracotta cuneiform tablet. 1 ¼" x 1 ½" 2200 BC**$300**
43452 Asian Marble bust of Kuan Yin. 11" x 9 ½" 400 AD..**$1,500**
43883 Egyptian Soapstone cat amulet. 1 ½" 305-30 BC.....**$180**
46112 Prehistoric Stegosaurus dinosaur egg from the Henan Provenance, China. Cretaceous Period. 3 ¼" 65 Million Years Old.....**$500**
46335 Greek Silver Philip II tetradrachm coin. 1" 359 BC.....**$1,200**
46342 Greek Silver Alexander the Great drachm. ½" 315-294 BC..**$150**
46602 Egyptian Alabaster vessel. 5" x 4" 1085-715 BC.....**$800**
46615 Asian Polished and magnetic meteorite. 1 ¼ lbs. 2 ½"..**$500**
46635 Prehistoric Tear-drop shaped amber pendant with a prehistoric bee. 1 ¾" 12 Million Years Old.....**$300**
46883 Greek Silver tetradrachm coin of Athena. 1" 400 BC....**$1,200**
46921 Egyptian Soapstone Eye of Horus amulet.1 ½"600 BC....**$200**
47291 Egyptian Detailed green glazed limestone Isis and baby Horus. Ptolemaic 8 ¾" x 4" x 2 ¼" 305-30 BC.....**$3,500**
47337 Egyptian Limestone heart scarab with Horus, the sky God, on top. Hieroglyphs on the bottom. 3 ¾" x 2 ½" 663-525 BC.....**$1,500**
47350 Egyptian Faience hippopotamus.2 ½" x 1 ¼" 1570-1342 BC **$800**
47546 Egyptian Wooden panel from a sarcophagus, with a Queen worshipping Osiris. 26th Dynasty.10" x 6" 663-525 BC.....**$3,000**

CHRISTMAS DELIVERY GUARANTEED!

All major credit cards accepted. Rush shipping is available.
All items are guaranteed authentic and come with a
LIFETIME CERTIFICATE OF AUTHENTICITY!
10 day return priviledge, less shipping.

THE GREAT COURSES®



Solve Ageless Mathematical Riddles

Great math riddles and paradoxes have a long and illustrious history, serving as both tests and games for intellectual thinkers across the globe. In addition to being fun, brain exercises are as fundamental to staying sharp as physical exercise is to staying fit.

If you enjoy deciphering puzzles, then this course is perfect for you. Award-winning Professor of Mathematics David Kung infuses each lesson of his 24 lectures with fun and interesting stories and real-life riddles, making this one of the most intriguing and entertaining math courses available.

This mesmerizing course will have you contemplating everything from the enthralling paradox of paradoxes to the potential pitfalls of buying apples—using basic logic and math principles as the fundamental connector to solve exciting, mind-bending mysteries.

Offer expires 11/12/15

THEGREATCOURSES.COM/6DISC

1-800-832-2412

Mind-Bending Math: Riddles and Paradoxes

Taught by Professor David Kung
ST. MARY'S COLLEGE OF MARYLAND

LECTURE TITLES

1. Everything in This Lecture Is False
2. Elementary Math Isn't Elementary
3. Probability Paradoxes
4. Strangeness in Statistics
5. Zeno's Paradoxes of Motion
6. Infinity Is Not a Number
7. More Than One Infinity
8. Cantor's Infinity of Infinities
9. Impossible Sets
10. Gödel Proves the Unprovable
11. Voting Paradoxes
12. Why No Distribution Is Fully Fair
13. Games with Strange Loops
14. Losing to Win, Strategizing to Survive
15. Enigmas of Everyday Objects
16. Surprises of the Small and Speedy
17. Bending Space and Time
18. Filling the Gap between Dimensions
19. Crazy Kinds of Connectedness
20. Twisted Topological Universes
21. More with Less, Something for Nothing
22. When Measurement Is Impossible
23. Banach-Tarski's 1 = 1 + 1
24. The Paradox of Paradoxes

Mind-Bending Math: Riddles and Paradoxes
Course no. 1466 | 24 lectures (30 minutes/lecture)

SAVE $190

DVD ~~$269.95~~ **NOW $79.95**
+$10 Shipping, Processing, and Lifetime Satisfaction Guarantee
Priority Code: 108324

For 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available anytime, anywhere. Download or stream to your laptop or PC, or use our free mobile apps for iPad, iPhone, or Android. Over 550 courses available at www.TheGreatCourses.com.